Richard L. Garwin
IBM Research Division
Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598
(914) 945-2555

November 1, 1989
(Via Airborne Express)

New York Times Archive

Mr. John P. Schiffer
Physics Letters B
Editor of Experimental Intermediate-
Energy and Heavy-Ion Nuclear Physics
Physics Division - 203
Argonne National Laboratory
Argonne, IL 60439-4843

Dear John,

Sorry not to have been in Washington these last two days to help with the final report. I write this on the airplane Tuesday morning GVA-JFK, in order to provide some additional information that may be helpful to our Fusion Products Group, and also to some of the other groups. Accordingly, I am copying Bill Woodard, both for the record and so that he can send out the Appleby data, in particular, to those responsible for the section on Excess Heat.

I received all of this material from Douglas R.O. Morrison, of CERN, who has been responsible for the Cold Fusion News distributed by E-mail approximately each week since April. Indeed here is issue "No. 20" including information on Morrison's talks in Salt Lake City and at Texas A&M

The next item is the tabulated data "Electrolysis of 0.1 M LiOD Using a Palladium Cathode ..." (provided by Appleby to D.R.O. Morrison during Morrison's visit) and given by D.R.O. Morrison to me 10/30/89. Apparently, Appleby continues to present the positive data, all of which was obtained 05/11-15/89, while all data after that time (05/27-31/89) was entirely negative and never mentioned by Appleby (according to Morrison). I note from the Table that Experiment No. 8 has no voltage below 4.70 V, while no data after that has voltage above 4.53 V. This may well be accounted for by the fact that no current before 05/16/89 was below 97.0 mA, and no current after that was above 97.0 mA.

I have seen some notes taken at the NSF/EPRI meeting in Washington 10/16-18/89. This quotes Al Bard as saying "that the calorimetric evidence was getting firmer." It also quotes Nate Lewis (or at least implies he said) "that he found their results the most convincing to date". (This refers to Orlani and Yaeger). I shall write both Allen and Nate to see what they believe, although you may already know this from our meeting in Washington.

Next is a paper on the "Gran Sasso Underground Laboratory" work, where they saw a "shot" signal in all detectors and some "burst signals." I provide this without comment other than to note (page 5) that the bare He3 counter provided more counts than the moderated He3 counter-- for which the authors provide no credible explanation, and for which I have been unable to think of one either.

Next is a paper from Culham "Experimental Search," which is entirely negative. On page 9, the authors note inexplicable increases in counting rate from individual counters or counter sets, which would have been taken as positive results except for the availability of other counters exposed to the same source.

Next, is a paper from Garching that is entirely negative.

Next is a paper from the Paul Scherrer Institut (Switzerland), also entirely negative, which has some quite sensitive results on the absence of He3 and He4 from fusion. Unfortunately, their D2O initially contained a lot of tritium, and there is some He3 from the beta decay of tritium.

Next is a letter from J.O'M. Bockris to D. Morrison, explaining that negative results "are not really negative, they mainly consist of people who did not electrolyze long enough." It is apparently like a winning strategy at cards, where if you only play long enough you will (with some probability) come out (temporarily) ahead.

Best regards. I await with interest the product of our Panel meeting of 10/30-31/89.

Sincerely yours,

Richard L. Garwin

Encl:

10/20/89 Cold Fusion News No. 20 from D.R.O. Morrison, CERN. (102089DROM)

10/30/89 Tabulated Appleby data provided by D.R.O. Morrison, "Electrolysis of 0.1 M LiOD Using a Palladium Cathode in an 'Open' Electrolysis Cell." (103089DROM)

09/15/89 "Results of the 1st Generation Experiments, at

New Energy Times Archive

Gran Sasso Underground Laboratory, on Nuclear Cold Fusion," by F. Celani et al. (091589..FC)

09/00/89 "Experimental Search for 'Cold Fusion' in the Deuterium-Titanium System," G.M. McCracken et al., Culham Laboratory. (090089GMMC)

07/24/89 "IPP Efforts on Cold Fusion," by J. Roth et al., a final report of efforts at IPP Garching on research concerning cold nuclear fusion. (072489..JR)

08/31/89 "Experimental Investigation of Cold Fusion Phenomena in Palladium," by J.P. Blaser et al, Paul Scherrer Institut. (083189.JPB)

10/26/89 LTR J.O'M. Bockris to D.R.O. Morrison. (102689JOMB)

cc:

- J.P. Schiffer, (Via BITNET to SCHIFFER at ANLPHY).
- J. Bigeleisen, (Via BITNET to JBIGELEI at SBCCMAIL).
- D.C. Hoffman, (Via BITNET to HOFFMAN at LBL.GOV).
- S.E. Koonin, (Via BITNET to KOONIN at CALTECH).

> J. Bigeleisen, Stony Brook (Via Airborne Express).
> D.C. Hoffman, Berkeley (Via Airborne Express).
> S.E. Koonin, Caltech (Via Airborne Express).
> W.L. Woodard, DOE (Via Airborne Express).

RLG:jah:305%JPS:110189.JPS

New Energy Times Archive

19 OCT 89 11:91 R.L. GARWIN

DOE F 1325.7
0-691
Exception to SF approved by NARS, June 1978

12556

UNCLASSIFIED

1. INSERT ABOVE, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY

2. MESSAGE CONTAINS WIRE DATA?
("X" appropriate box. Message Center will not transmit message unless one box is marked.)
☐ YES ☒ NO

U.S. DEPARTMENT OF ENERGY
TELECOMMUNICATION MESSAGE
(See reverse side for instructions.)

1328

3. USE WHEN REQUIRED
THIS DOCUMENT CONSISTS OF 5 PAGES
NO. ____ OF ____ COPIES, SERIES ____

4. PRECEDENCE DESIGNATION ("X" appropriate box):

	FOR NORMAL USE		EMERGENCY USE ONLY	
ACTION:	☒ Routine	☐ Priority	☐ Immediate	☐ FLASH
INFO:	☐ (6 Hrs.)	☐ (3 Hrs.)	☐ (30 Mins.)	☐ (ASAP)

5. TYPE OF MESSAGE ("X" appropriate box)
☐ Single Address
☒ Multiple Address
☐ Title Address
☐ Book Message

FOR COMMUNICATIONS CENTER USE ONLY
MESSAGE IDENTIFICATION
NR: DTG: Z

6. FROM DOE FORRESTAL

7. OFFICIAL BUSINESS (TIME) 10:00 A.M. P.M.
Bill Woodard
(Signature of authorizing official)

8. DATE 10/19/89

9. TO

John Huizenga, Co-Chairman
University of Rochester
Rochester, NY 14627
FAX (716) 473-6889

Norman Ramsey, Co-Chairman
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

Allen J. Bard
University of Texas
Austin, TX 78712
FAX (512) 471-8696

Jacob Bigeleisen
SUNY, Stony Brook
St. James, NY 11780
FAX (516) 632-7960

Howard K. Birnbaum
University of Illinois
Urbana, IL 61801
FAX (217) 244-2278

Michel Boudart
Stanford University
Stanford, CA 94305
FAX (415) 725-7294

Clayton F. Callis
American Chemical Society
St. Louis, MO 63131
FAX (314) 569-3712

*Mildred Dresselhaus
MIT, Room 13-3005
Cambridge, MA 02139
FAX (617) 253-2112

BE BRIEF - ELIMINATE UNNECESSARY WORDS

COMMUNICATIONS CENTER USE ONLY
FACSIMILE
297 19 OCT 89 11:14
070
020103

10. ORIGINATOR *(On separate lines, enter Name, Routing Symbol, & Tel. No.)*
Bill Woodard
EH-6
6-5444

11. DERIVATIVELY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to Administrative and Criminal Sanctions.
Derivative Classifier: (Name) ____
(Title) ____
Declassify on: (Date or Event/OADR) ____
Derivatively Classified by: ____ (Guide or Source Document)

12. ORIGINALLY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to Administrative and Criminal Sanctions.
Originally Classified by: (Name) ____
(Title) ____
Declassify on: ____ (Date or Event/OADR)

13. ☐ RESTRICTED DATA
This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Unauthorized disclosure subject to Administrative and Criminal Sanctions.
DERIVATIVE CLASSIFIER ____ (Name and Title)

14. ☐ FORMERLY RESTRICTED DATA
Unauthorized disclosure subject to Administrative and Criminal Sanctions. Handle as Restricted Data in Foreign Dissemination Section 144.b Atomic Energy Act, 1954.
DERIVATIVE CLASSIFIER ____ (Name and Title)

15. INSERT BELOW, CLASSIFICATION LEVEL UNCLASSIFIED, OR OFFICIAL USE ONLY
UNCLASSIFIED

New Energy Time Archive

2 #1328

Larry R. Faulkner
University of Illinois
Urbana, IL 61801
FAX (217) 244-8068

T. Kenneth Fowler
University of California
Berkeley, CA 94720
FAX (415) 643-9685

Richard L. Garwin
IBM Corporation
Yorktown Heights, NY 10598
FAX (914) 945-2141

Joseph Gavin, Jr.
Grumman Corporation
Bethpage, NY 11714
FAX (516) 575-3631

William Happer, Jr.
Mitre Corporation
La Jolla, CA 92038
FAX (619) 455-3943

Darleane C. Hoffman
Lawrence Berkeley Laboratory
Berkeley, CA 94720
FAX (415) 486-4515

Steven E. Koonin
CALTECH
Pasadena, CA 91125
FAX (818) 564-8708

Peter Lipman
US Geological Survey
Denver, CO 80225
FAX (303) 236-5448

Barry Miller
AT&T Bell Laboratories
Murray Hill, NJ 07974
FAX (201) 582-3609

David Nelson
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

John P. Schiffer
Argonne National Laboratory
Argonne, IL 90439
FAX (312) 972-3903

Dale Stein
Michigan Technology University
Houghton, MI 49931
FAX (906) 487-2398

Mark Wrighton
MIT, Building 6, Room 335
Cambridge, MA 02139
FAX (617) 258-7652

New Energy Times Archive

3 1436

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 586-5444

October 19, 1989

TO MEMBERS OF THE COLD FUSION PANEL

Dave Goodwin attended a NSF/EPRI Workshop this Monday and Tuesday and asked me to send you his attached summary notes as soon as possible.

William L. Woodard
Panel Secretary

New Energy Times Archive

4 15/123

27% → 54%!!

Notes on NSF/EPRI Workshop

NRL: Up to a 100% increase in Pd-1061!
"NOT FOR PUBLIC RELEASE AND NOT FOR ATTRIBUTION"

Who? "

Bockris: 10 U.S. groups with heat

Pons: 20 mW detection limit, blanks: ± 1 mW
K: ± 0.15% based on 33 calibrations
1 Aug. to on-going: 16 megaJ in, 36 megaJ out

Oriani (Minn.): + 200 KJ excess of 2,500 KJ in
Hollywood Abstract: 50 w/cc, 11 hr. 2.2 megaJ/cc

Wadsworth: 38 x more heat out than burning all D2 in rod

Huggins: > 30 to 50% excess heat in open cells
Recombiner: 10% excess heat
+ 1 W or + 3-4 W (much scatter in data)

Yeager (Case): Up to + 10% excess heat
2 x T expected from isotopic sep.

Hutchinson (Oak Ridge): Up to + 9 W (+ 20%)

Teller: Suggests doping Pd rod with U-235 and/or replacing Li with Be.

Rafelski: May be possible to have an energy lower than the n producing branch but higher than the T producing branch.

Jones:
- Penn State (Howard Pickering) has similar n bursts
- Will exam n time structure; may use LAMPF equipment

New Energy Times Archive

S 1#1328

SUMMARY ITEMS

(1) Isotopic analysis of the electrode, especially of the surface (and of the electrolyte) should be considered at least as high of a priority as n, T, He-3 and He-4 (Isotopic analysis is reportedly about 10^2 less sensitive than He). Geophysics (and astrophysics) data are of similar priority as p, x-rays, gammas and betas. Teller stated Livermore has measured Li-6 depletion in 1st micron of surface (measured to 3 microns).

(2) Consideration should be given to having "new experiments in high radiation fields."

(3) National Labs should attempt to confirm positives (some funding required).

(4) The theory group noted the superconductivity "inverse isotope effect" of Pd-D (Tc lower for heavier isotopes).

New Energy Times Archive

COLLEGE OF NATURAL SCIENCE
THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Chemistry · Austin, Texas 78712-1167 · FAX (512) 471-8696
BARD FAX: 512-471-0088

October 19, 1989

TO: Cold Fusion Panel

FROM: Allen J. Bard

RE: Brief report on NSF/EPRI Workshop (October 16-18, 1989)

The overall atmosphere of the workshop was definitely more "up-beat" than many other recent meetings in the sense of belief in the reality of "anomalous" effects and at least the strong possibility that these effects represent nuclear processes of some sort. This probably is a reflection of the choice of participants, which included a large number of "believers". For example, among those who have looked at calorimetry and excess heat were Pons, Fleischmann, Appleby, Bockris, Huggins, Hutchinson (ORNL), Oriani, Wadsworth, and Yeager, vs. Myles (ANL), Bray (GE), and Lewis, with McKubre (SRI) in the middle. It also seemed to me that most of the EPRI attendees were committed to supporting research in this area and were looking for confirmation from the participants.

A thumbnail sketch of some of the presentations (emphasizing new results) follows.

Mantove continues to see n-burst in dry Ti-alloy systems (30-40% of samples).

Wolf has recent finding (in Martin Pd/Ni cell) of high t-level after extensive electrolysis (1.4×10^8 dpm/mL). No secondary n or γ. He thinks it may be contamination from cell materials.

Bockris continues to report excess heat and t. He has one new experiment showing weak temporal correlation between heat and t (t at 1% expected level from heat).

Storms and Talcott also reported on t and do not believe it is contamination.

Robinson and O'Grady (NRL) presented very intriguing results which they asked not be discussed outside the meeting.

Pons/Fleischmann: Showed new experiments still carried out in original calorimeter design. Mode of calibration and calculation of heat output seems to me to have changed (although Pons said this was the way they always did it). They now say radiative, rather than conductive, heat transfer term predominates and calculate

$$k_I = k'(T_c^4 - T_b^4).$$

Pons promised to send me full details. He also reported on number of Pd/H_2O blanks in which power out = power in to better than 1%. He showed a couple of "bursts" and said (in response to a question) he had an oscilloscope on the cell during the burst and cell voltage variation was 4 mV. [Bockris also said he routinely monitors his cells with an oscilloscope during "bursts".]

101989.AJB

New Energy Times Archive

Page two
Cold Fusion Panel
October 19, 1989

Maximum t is 8 times background. n-detection was said to be "tough", but feels they see 2.223 MeV γ, but "not ready to talk about these results." He says all of his small electrodes (diam. 0.1, 0.2, 0.4 cm) produce some excess heat, but 0.8 cm never does (total of some 30 electrodes).

Oolan discussed new results reporting excess heat in 2 of 3 open cells in Seebeck type calorimeter (ca. 2-21%). The work seemed well done, and a preprint of the work is being circulated to the committee. He sees no n, t, γ.

Wadsworth reported on heat bursts, mostly from earlier work. Says that after they improved their constant temperature bath and went to a closed (recombination) cell, they haven't seen a heat burst (last 2 months), but this involved a different batch of Pd and D_2O.

Appleby mostly reviewed older work. With new closed (recombination) cell, he reported that one run gave 4% excess heat, but with new Pd and lower current density.

Huggins talked about new calorimeter and closed cell system. With one cell running since October 11, has steady excess heat of 3.6 to 5.8%, with repeated short bursts associated with large cell voltage excursions.

Yeager reported preliminary results with Tronac calorimeter. Saw excess heat of 0, 2.7, and 8.7% in Pd/D_2O in closed (recombination) cell vs. 0 (Pd/LiOH) and 0 (Pt/LiOD). Found t in one open-cell type experiment at 1868 dpm/mL.

McKubre reviewed older results already presented to panel. He has new closed (D_2 pressurized) cell running, but no results yet.

J. Bray (GE) discussed possible errors in data treatment and calibration in P/F-type calorimetry that seemed aimed directly at their reported excess heat measurements. He does not find excess heat.

J. Warth (Englehard) discussed calorimetric measurements, but requested this remain confidential.

Hutchinson (ORNL) is doing open cell calorimetry and is convinced he is seeing excess heat that scales with current (5-10%) (no H_2O controls). He promises to supply details of work to committee.

I was not in attendance during the Jones presentation, and I leave for others to summarize (if they desire) the discussions of theory by Teller, Baym, Kim, Whaley, Rafelski and others.

New Energy Times Archive

DOE F 1325.7
(3-83)

Exception to SF 14, Approved by NARS, June 1978

1. INSERT ABOVE, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY

2. MESSAGE CONTAINS WEAPON DATA?
("X" appropriate box. Message Center will not transmit message unless one box is marked.)
☐ YES ☒ NO

U.S. DEPARTMENT OF ENERGY
TELECOMMUNICATION MESSAGE
(See reverse side for instructions.)

3. USE WHEN REQUIRED
THIS DOCUMENT CONSISTS OF 4 PAGES
NO. ____ OF ____ COPIES, SERIES ____

4. PRECEDENCE DESIGNATION ("X" appropriate box):

	FOR NORMAL USE		EMERGENCY USE ONLY	
ACTION:	☒ Routine	☐ Priority	☐ Immediate	☐ FLASH
INFO:	☐ (6 Hrs.)	☐ (3 Hrs.)	☐ (30 Mins.)	☐ (ASAP)

5. TYPE OF MESSAGE
("X" appropriate box)
☐ Single Address
☒ Multiple Address
☐ Title Address
☐ Book Message

FOR COMMUNICATION CENTER USE
MESSAGE IDENTIFICATION
NR: DTG: Z

6. FROM
William Woodward

7. OFFICIAL BUSINESS
William Woodward
(Signature of authorizing official)
TIME 4:20 ☐ A.M. ☐ P.M.

8. DATE
10-19-89

9. TO

John Huizenga, Co-Chairman
University of Rochester
Rochester, NY 14627
FAX (716) 473-6889

Norman Ramsey, Co-Chairman
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

Allen J. Bard
University of Texas
Austin, TX 78712
FAX (512) 471-8696

Jacob Bigeleisen
SUNY, Stony Brook
St. James, NY 11780
FAX (516) 632-7960

Howard K. Birnbaum
University of Illinois
Urbana, IL 61801
FAX (217) 244-2278

Michel Boudart
Stanford University
Stanford, CA 94305
FAX (415) 725-7294

Clayton F. Callis
American Chemical Society
St. Louis, MO 63131
FAX (314) 569-3712

*Mildred Dresselhaus
MIT, Room 13-3005
Cambridge, MA 02139
FAX (617) 253-2112

COMMUNICATION CENTER USE ONLY
69 69
OCT 19 '89
7001
CCCCCC

BE BRIEF – ELIMINATE UNNECESSARY WORDS

10. ORIGINATOR (On separate lines, enter Name, Routing Symbol, & Tel. No.)
William Woodward
ER-6
586-5767

11. DERIVATIVELY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to Administrative and Criminal Sanctions.
Derivative Classifier: (Name) (Title)
Declassify on: (Date or Event/OADR)
Derivatively Classified by: (Guide or Source Document)

12. ORIGINALLY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to Administrative and Criminal Sanctions.
Originally Classified by: (Name) (Title)
Declassify on: (Date or Event/OADR)

13. ☐ RESTRICTED DATA
This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Unauthorized disclosure subject to Administrative and Criminal Sanctions.
DERIVATIVE CLASSIFIER _____ (Name and Title)

14. ☐ FORMERLY RESTRICTED DATA
Unauthorized disclosure subject to Administrative and Criminal Sanctions. Handle as Restricted Data in Foreign Dissemination Section 144.b Atomic Energy Act, 1954
DERIVATIVE CLASSIFIER _____ (Name and Title)

16. INSERT BELOW, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY

New Energy Times Archive

Larry R. Faulkner
University of Illinois
Urbana, IL 61801
FAX (217) 244-8068

J. Kenneth Fowler
University of California
Berkeley, CA 94720
FAX (415) 643-9685

Richard L. Garwin
IBM Corporation
Yorktown Heights, NY 10598
FAX (914) 945-2141

Joseph Gavin, Jr.
Grumman Corporation
Bethpage, NY 11714
FAX (516) 575-3631

William Happer, Jr.
Mitre Corporation
La Jolla, CA 92038
FAX (619) 455-3943

Darleane C. Hoffman
Lawrence Berkeley Laboratory
Berkeley, CA 94720
FAX (415) 486-4515

Steven E. Koonin
CALTECH
Pasadena, CA 91125
FAX (818) 564-8708

Peter Lipman
US Geological Survey
Denver, CO 80225
FAX (303) 236-5448

Barry Miller
AT&T Bell Laboratories
Murray Hill, NJ 07974
FAX (201) 582-3609

David Nelson
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

John P. Schiffer
Argonne National Laboratory
Argonne, IL 90439
FAX (312) 972-3903

Dale Stein
Michigan Technology University
Houghton, MI 49931
FAX (906) 487-2398

Mark Wrighton
MIT, Building 6, Room 335
Cambridge, MA 02139
FAX (617) 258-7652

New Energy Times Archive

10/19/89

Date: 18-OCT-1989 14:11:36.57
From: "SCHIFFER@ANLPHY (312)972-4066 FAX:972-3903" <SCHIFFER@ANLPHY>
To: rlg2@yktvmv.BITNET
Subject: next draft
X-ANJE-To: BIGELEISEN,GARWIN,HOFFMAN,KOONIN,SCHIFFER

To Fusion Products Subgroup
From J. Schiffer

I have included most of the changes that were in the marked up copy sent me by Dick Garwin. There are still some changes in the neutron section (e.g. Menlove) that I have asked Garwin to try to do. Also we need to include a statement on 3He and 4He where I have not yet found the references. Some changes were incorporated to the tritium section in accordance with Garwin's note from the meeting -- some others will have to wait for Jake. WE ARE SUPPOSED TO HAVE THE NEXT DRAFT TO WASHINGTON BY THE 24TH ON A HARD DISK -- SO PLEASE GET ME ANY CHANGES BY THIS WEEKEND. Thanks for your help,

John

PS the present version may have some cosmetic problems since it had to be converted from a 'MASS_11' version into an ASCII file for transmittal, but I think it should be legible.

Draft - Oct. 18, 1989

FUSION PRODUCTS

I. INTRODUCTION

The nuclear fusion of deuterium has been studied intensively for over 40 years. The reaction between two low energy deuterium nuclei can proceed in three ways:

(a) D + D --> 3He (0.82 MeV) + n (2.45 MeV)

(b) D + D --> T (1.01 MeV) + p (3.03 MeV)

(c) D + D --> 4He + gamma (23.847 MeV)

The reactions (a) and (b) have been studied down to deuteron energies of a few keV and the cross sections found to be equal to within 10%. In the interaction of deuteron beams with heavy ice or metal deuteride targets, almost one 2.45 MeV neutron is produced (with an accompanying 3He) for every triton (with an accompanying proton). This near-equality of neutron and proton branches of the D + D reaction, shown in figure 1, is a reflection of the basic symmetry of nuclear forces between proton and neutron, disturbed only slightly at the MeV energies of the emerging particles by the Coulomb interaction, which is not symmetrical between proton and neutron. The cross section for reaction (c) is on the order of 10**7 lower than the first two.

All nuclear reactions at low energies between two deuterons are retarded by the Coulomb repulsion between the positively charged nuclei -- the penetration of the repulsive Coulomb barrier changes exponentially with bombarding energy: for instance the measured cross section for reaction (b) changes from 0.2 microbarns at 2.7 keV to 35 millibarns at 100 keV. But the ratios for the three reactions appear to be constant

New Energy Times Archive

below 100 keV.

Any fusion between deuterium nuclei must lead to detectable fusion products. For reaction (a) neutrons are the most easily detected product, by direct counting. For (b) the protons or tritons can be detected by direct counting, and the accumulated tritium could also be identified by its radioactivity, albeit with lower sensitivity. Neutron counting is perhaps again the most useful technique here, since neutrons must be produced by the energetic tritons interacting with ~~other~~ deuterons in the material at the rate of 1 neutron for every 10,000 to 50,000 tritons. Reaction (c) leads to readily detectable high energy gamma rays and 4He; the latter may be identified by mass spectroscopic measurements, whose sensitivity is low -- though the 10**17 levels implied by 1 watt of heat should be readily observable.

In the following we summarize ~~the experimental evidence~~ on these fusion products. First we discuss the ~~plausibility~~ of reactions at room temperature and the issue of whether the constancy of the three reaction modes is a reasonable extrapolation to such low energies. Then the data on neutrons, charged particles, gamma rays and tritium are summarized. Finally, some comments are included on unconventional explanations, and geochemical evidence is summarized on proposed cold fusion in the interior of the earth.

We have used published material, where available, or material prepared for publication and presented at formal meetings or as preprints distributed without restriction as to citation. It is important to include not only positive results, that claim the detection of fusion products, but also the negative ones, that have attempted to replicate the experimental procedure of the former and failed to detect anything above background, at a level of sensitivity substantially better than the positive results.

II. THE REACTION PROCESS

Fusion reactions can occur only if during a nuclear collision the Coulomb barrier is surmounted or, at low energies, penetrated so that the nuclei approach each other within about 10**-12 cm. This distance is some 10000 times smaller than the typical separations of atoms in ordinary matter. The penetration of the barrier at low energies takes place through a well-understood quantum mechanical phenomenon called tunneling that allows fusion to occur in collisions far less violent than might be required otherwise.

In the thermonuclear fusion that occurs in stars and in laboratory "hot fusion" experiments, high temperatures (tens of millions of degrees or more) provide the violent collisions required to produce fusion. However, in the so- called cold fusion experiments, it is claimed that the penetration of the barrier through quantum mechanical tunneling has somehow become so effective as to allow fusion to occur even at room temperatures. Further, some experimenters claim that the nuclear process is changed by an unspecified mechanism so as to alter dramatically the nature of the reaction products. Each of these claims must be understood as separate and equally surprising.

Some simple calculations illustrate how remarkable is the claim of fusion at room temperatures. The fusion rate for the two deuterium nuclei in a deuterium molecule (where they are even closer than they are when embedded in a metal) results in one fusion per year in a solar mass of deuterium. Further, the fusion of protons and deuterons is calculated to

New Energy Times Archive

be 10**9 times faster than the D + D reaction claimed to have been observed (although it is still extraordinarily slow). No mechanism is known by which these rates could be enhanced by the 40- 50 orders of magnitude required to agree with the reported observations.

One mechanism invoked for enhancing cold fusion rates is screening by "heavy" electrons. ~~It is true that~~ endowing the electron with a hypothetical mass some 5-10 times larger than it actually has would enhance fusion rates sufficiently to agree with most cold fusion claims [Ko]. It is also true that there are "heavy fermion" materials whose thermodynamic properties at very low temperatures are characteristic of quasiparticles with masses many times those of a free electron. However, this phenomenon is understood as involving long- wavelength excitations in which strong correlations "dress" electrons near the Fermi surface. As such, heavy fermions extend over many lattice sites. Because the tunnelling in nuclear fusion occurs at distances smaller than one lattice site, only the short-wavelength "bare" electron excitations are relevant for screening, and cannot enhance the fusion rate significantly.

IIa. The D + D Branching Ratios.

The relative rates of reactions (a), (b), and (c) are called the branching ratios and are a crucial issue in the discussion of some cold fusion claims. These reactions have been studied in laboratory experiments using accelerators for deuteron energies above a few keV [Kr]; the smallness of both cross sections prevents reliable measurements at lower energies. The ratio between the two rates exhibits a weak energy dependence and is near 1.0 at the lowest energies as seen in figure 1. Data from muon-catalyzed D + D fusion [Bal], which probes an even lower energy range, is still consistent with nearly equal rates.

A branching ratio of more than one million would be required to explain experiments that claim to observe high fusion rates (either through heat or tritium production) without a corresponding high neutron flux. As "cold fusion" is thought to occur at energies on the order of eV, this is not directly ruled out by the data discussed above. However, no mechanism is known for inducing such a rapid energy-dependence in the branching ratio. The Oppenheimer-Phillips process involving the Coulomb break-up of the deuteron has sometimes been invoked in this regard. However, this process is not effective at low energies in the D + D system.

IIb. The Gamma Branch.

Some researchers have hypothesized that the D + D --> 4He + gamma (23.847 MeV) reaction, which is ordinarily some 10**7 times weaker [Bar] than reactions (a) and (b) in which two fragments are produced, somehow dominates in cold fusion situations. To be consistent with the lack of neutrons, a very large enhancement of the gamma branch by a factor somewhere in excess of 10**13 would be required. We know of no way whereby the atomic or chemical environment can effect such an enhancement, as this ratio is set by phenomena on a length scale some 10**4 times smaller than the atomic scale.

Even if there were such an enhancement, the absence of observed high-energy electromagnetic radiation (photons, positrons, or fast electrons) rules out such a mechanism. While direct coupling to the lattice through unspecified mechanisms has been invoked to suppress such radiation, any such coupling must occur through the electromagnetic field and would result in some observable high-energy radiation.

New Energy Times Archive

IIc. The p + D Reaction.

It has been suggested that an alternative fusion process could be the reaction

p + D --> 3He + gamma (5.49 MeV)

for which the penetration factors are still overwhelmingly small at room temperature, but somewhat less so than for the D + D process [Ko]. This reaction produces a readily observable gamma ray and if it is to account for 1 watt of heat, then it should also produce 3He in observable concentrations.

IId. Secondary Yields from Fusion Products.

i) Neutrons from tritium. The tritons produced in reaction (b) have an energy of 1.01 MeV. This energy must be lost in the immediately surrounding material, which in an electrolytic cell is either the Pd electrode saturated with deuterium, or heavy water. The tritons will therefore bombard the deuterium in the surrounding material. The T + D reaction is a rich source of neutrons, with a cross section that reaches 5 barns (i.e., 5x10**-24 cm2) at 0.12 MeV, then falls to about 0.7 barns at 0.5 MeV, and reaches slightly below 0.3 barns at 1 MeV. For the 1.01 MeV tritons from the D + D reaction an average cross section is about 1.2 barns. For tritons that are stopped in PdD this translates into a neutron yield between 1.5 and 2x10**-5 neutrons per triton; for tritons stopping in heavy water there are about 9x10**-5 per triton.

ii) Coulomb excitation of Pd by protons. The even Pd isotopes (104, 106, 108, 110) with abundances of 11, 27, 26, 12 % have first-excited 2+ states at 555, 512, 434, 374 keV and B(E2) values between 0.5 and 0.8 barns. The cross sections for Coulomb excitation are in the vicinity of 20 to 50 millibarns and thus the yields expected are 2 to 5x10**-6 per proton. In palladium the half thickness for absorption of these gamma rays is about 4 mm, in water it is several cm.

In terms of power, there must be about 10**8/sec secondary neutrons per watt of fusion, even if direct neutron production is completely suppressed and all the reaction goes into tritium production. Under these conditions there must also be slightly under 10**7 secondary photons per second, of well defined energies, in the 500 keV range.

III. NEUTRONS

IIIa. Detection.

Neutrons are a major product of D + D fusion. Neutrons are convenient particles to detect, since they interact only with the nuclei of atoms and so can emerge from reaction vessels of substantial size unscathed and without having lost energy. Similarly, large counters can be used without the problem of thin entrance windows, since neutrons enter into the volume of the counter without difficulty. Some simple facts about neutron detection are summarized in Appendix A.

IIIb. Initial claims.

The University of Utah (UU) group in its initial publication [Fle] claimed the detection of neutrons from D + D by virtue of the gamma ray emitted by the capture of the moderated neutron in the water bath surrounding the electrolytic cells. A narrow peak in the pulse-height

New Energy Times Archive

spectrum from the NaI scintillator was published, narrower than is possible with this type of detector, and with internal inconsistencies in the energy scale as pointed out by a group at MIT [Pe]. The photo peak at 2.2 MeV obtained at MIT from Cf spontaneous fission neutrons moderated in water and radiatively captured on protons is accompanied by other peaks from natural background that enable one to calibrate the energy. Successive interchange between UU and MIT groups in the scientific literature has demonstrated that the claimed detection of neutrons by the proton capture gamma ray at UU was an artifact of the experimental apparatus.

The original publication from Brigham Young University (BYU) [Jo] presented the detection of neutrons as the sole experimental evidence for the existence of cold nuclear fusion. The neutrons were detected in a two-stage neutron counter -- first by the proton recoil in organic scintillator, followed within a few tens of microseconds by a signal from the capture of the moderated neutron on boron viewed by the same photomultipliers. This double detection of a single neutron serves substantially to reduce the ambient background due to gamma rays, although there remains background in the experiment due to gamma rays and to real neutrons from cosmic rays and other sources. The group at BYU has chosen to attempt to vary the experimental conditions in order to obtain a greater rate of D + D fusion, and so has not presented much more data than the original paper on the detection of neutrons with that counter. In fact, BYU has been working in collaboration with other groups, notably at LANL [Me], and also with a group at Yale University. The original claim of neutron detection five standard deviations above the background is somewhat reduced in statistical strength if one considers the degrees of freedom that are fixed by the presentation of a peak in one of a number of experiments and at a particular energy, and also the possible fluctuation in the cosmic-ray neutron background. Ordinarily, however, such a result can be improved through improved shielding or by moving to an underground site.

Typical of the latter is work by the group at Sandia National Laboratory, [Ald] in which a site was found with substantially less background and results presented for a limit on neutrons produced in electrolytic fusion. Similar results from the Frejus tunnel in France were also presented in Santa Fe. [DeCl]

Many claims have been made for the production and detection of neutrons produced in electrochemical cells, but these claims have mostly been withdrawn or moderated by the discovery of difficulties with the counter -- particularly with the BF3 counters used. Some counters are sensitive to humidity; others to microphonic noise (vibration), or to other afflictions. Some limits on reported neutron fluxes, compared to the flux reported by the BYU group, are summarized in Table I.

IIIc. Dry Fusion.

Results presented in April 1989 by a group at Frascati [DeN] opened a different area of investigation for the study of D + D cold nuclear fusion. In this work, deuterium gas at 60 atmospheres pressure (60 bar) was allowed to contact titanium lathe turnings in a stainless steel reaction vessel, and the temperature of the sample was varied either by heating or by cooling. No neutrons were observed from the hydriding reaction, at room temperature or at elevated temperature, when viewed by a nearby BF3 counter. However, after cycling to liquid nitrogen temperature (77 K), bursts of counts were observed -- typically on the order of 20 counts per burst over a period of 60 microseconds. One set of counts, obtained by cycling to nitrogen temperature, shows neutrons mainly in

these bursts.

A different type of neutron emission was also claimed by the Frascati group [DeN] following warming from nitrogen temperature over one weekend. The observed count rate follows a bell-shaped curve, rising to a peak of 300 neutrons per 10/minute counting interval, over some 5 hours. This important experimental result provoked great effort toward verification, both at Frascati and elsewhere. A recent private communication from M. Martone at Frascati have been confirmed. Neither the burst results nor the continuous neutron emissions from the D-Ti system or from any other dry fusion activity at Frascati. In addition, electrochemical cells produced no observable neutrons, and their operation was terminated in July.

*Additional care is needed as the rate of cosmic ray neutrons can fluctuate by 20% or more with variations in barometric pressure or with solar activity.

A group at LANL [Me] has conducted dry fusion work with Ti and Pd, and has presented results both at the Santa Fe meeting and in a preprint. This group at LANL uses high-efficiency systems that moderate any fast neutrons emitted from experimental cells, detecting the moderated thermal neutrons in 3He gas counters. Some bursts of neutron counts are observed 3000-5000 seconds after the sample is removed from liquid nitrogen, at sample temperatures of about -30 C. These bursts, of up to 100 neutrons at most, are seen in about 30% of the samples tested. An attempt to reproduce this effect at Sandia National Laboratory yielded negative results [Ald].

At the Santa Fe workshop, Moshe Gai of Yale presented results obtained in collaboration with Brookhaven National Laboratory, in which no neutrons were detected from electrolytic cells above the detection limit of 10**-25 n per D - D pair/sec [Ga].

Finally, a conference report from the Bhabha Atomic Research Center (BARC), India, [Iy] provides text and tabulated results from several groups at BARC. Fig. 1 of the BARC report shows counts from neutron detectors observing a large electrolytic cell, with an estimated 2x10**7 neutrons in the 5 minutes following an overpower trip of the electrolyzer. Tritium and neutrons are observed at BARC from cathodes fabricated of PdAg alloy as well as from pure Pd. Fig. 2 of the BARC report shows dry fusion 3He counter output during gradual rise of temperature of 20 g of Ti while deuterium gas was being pumped off. It is also commented that samples could be loaded with deuterium gas at 1 bar and 900 C, and that "one such disc shaped button loaded on Friday 16th June began emitting neutrons on its own, almost 50 hours after loading. It produced (about) 10**6 neutrons over a 85-minute active phase. The background neutron counter did not show any increase in counts over this time."

IIId. Secondary Neutron ~~Production~~ Yields.

There are severe problems of consistency between the numbers of tritium atoms detected in some of the experiments discussed above and the number of neutrons. The BARC abstract reads, "The total quantity of tritium generated corresponds to about 10**16 atoms suggesting a neutron to tritium branching ratio less than 10**-8 in cold fusion." But, as discussed above there must be at least one neutron per 100,000 tritons if the observed tritium were originating from fusion, 1000 times more than was observed!

New Energy Times Archive

IV. CHARGED PARTICLES AND GAMMAS

A few experiments [Po,Pr,Re,Su] to measure the 3 MeV protons and/or the 1 MeV tritons produced in the reaction, D + D --> T + p, have been reported; they are summarized in Table II below. A variety of different methods has been used, but the lowest limit on charged-particle production appears to be that set by Price using plastic track detectors. Their setup was designed so that the light water control cell matched the heavy water cell as closely as possible. Electrolysis was performed for 13 days, and the cathode stochiometry was determined to be Pd(H,D)0.8. Both cells showed track production rates that agreed and were consistent with the alpha-particle emission rate for native Pd foils due to trace (ppm) impurities of the natural 238U and 232Th decay chains; however, no tracks due to protons with energies between 0.2 and 3 MeV or tritons with energies between 0.2 and 1 MeV were found. From these data Price [Pr] set limits on the fusion rate of less than 0.002 per cm3 per second. This value results in an upper limit of 8.3x10-26 fusions per D - D pair per second. This is about an order of magnitude lower than the limits obtained using Si surface barrier (SSB) techniques.

A limit on the fusion rate of 0.028 per cm3 per second or 1.2 x 10-24 fusions per D - D pair per second was obtained by Ziegler [Zi] using a SSB technique. Porter [Po] used a SSB detector to view the back of a 76 micron thick Pd foil cathode in a heavy water electrolysis cell. They obtained a limit of less than 6x10-25 protons per dd pair per sec at the 2 sigma level; chemical analysis of their electrolytes showed no evidence for anomalous increases in tritium concentrations. Sundqvist et al. [Su] also used a SSB technique to detect protons. The detector was placed close to Pd foil cathodes that were thin enough to allow all the protons produced to escape from the foil. All of their runs gave a null result within the statistical errors, resulting in a fusion rate of -2.1 (; 2.2) x 10**-24, if a bulk process is assumed.

Recently, Rehm [Re] has reported using a proportional counter to search for charged particles from electrolytic cells with Pd and Pt electrodes in 0.1 M LiOD in D2O. They obtained an upper limit of 4 x 10**-23 fusions per D - D pair per second, not as low as the limits using the other methods.

In summary, a variety of experimental techniques has been used in searches for charged particles; all of them set very low limits on fusion occurring via the D + D --> T + p. Most of these results set limits that are considerably less than Jones' [Jo] value of 1.00 (; 0.82) x 10**-23, (uncertainty calculated by Sundquist [Su]) fusions per D - D pair per second for the D + D --> 3He + n channel obtained from neutron measurements.

The upper limit of Price [Pr] of 8x10-26 fusions per dd pair per second is much below the average low rate inferred from the neutron measurements of Jones or even those of Menlove [Me]. The extremely low limits which the searches for charged particles (either protons or tritons) place on their production is inconsistent with the reported production of tritium via the cold fusion reaction.

IVa. GAMMA-RAY SEARCHES

A rare branch of the D + D reaction proceeds through capture, in which a 24-MeV gamma ray is emitted. Similarly, the p + D reaction is associated with a 5.49 MeV gamma ray. In several published searches no gamma rays that would be associated with the D + D or p + D capture

New Energy Times Archive

reactions were seen. They include a report by Henderson [He] who cites limits around 10**-23/sec 24-MeV gamma rays emitted per deuteron in various cells. Porter [Po] reports no 5.5 MeV gamma rays -- though no absolute limit is quoted. They also comment on the absence of K X-ray production from Pd. Greenwood [Gr] reports limits of 10**-23 for gamma rays above 1.9 MeV. Other negative results are quoted in the Santa Fe abstracts without quantitative detail. Lewis, et al., [Lew] report fewer than 4x10**-25 5.5-MeV gammas per second per D in a Pd cathode, and fewer than 2x10**-23 24-MeV gammas per second per D.

V. TRITIUM

One branch of the D + D reaction produces tritons and protons. Searches involving the direct detection of charged particles have yielded stringent negative results; so has the lack of neutrons. Searches have also been made for the tritium accumulated during the electrolysis of D2O with palladium cathodes, determining tritium content by detecting the radioactive decay of tritium. In such experiments it is important to determine the initial tritium content of the heavy water and recognize that the electrolysis of the heavy water will enrich the naturally occurring tritium in the heavy water.

The detection of tritium by measurement of its beta decay is inherently a less sensitive probe of the D - D reaction than the direct measurement of neutron or charged particle production. About 10**7 tritium atoms give 1 decay by beta emission per minute. The tritium content of normal water is about 10**-18 relative to hydrogen but, as discussed in Appendix B, the normal manufacturing of heavy water also enriches tritium, and thus heavy water currently being sold gives between 120 and 180 disintegrations per minute (dpm) from tritium decay.

Va. Null Experiments.

Most excess tritium reported to date in electrolytic cells can be accounted for by the electrolytic enrichment process. This includes the original report by Fleischmann and Pons [Fle], and experiments at ANL, [Gre,Red] BNL, [Da,McB,Wi2] Cal Tech, [Le2] CRNL, [Sc] INEL, [Lo] LLNL, [Al] NRL, [Er] ORNL, [Fu,Sc] Sandia, [Na] SRL, [Ra] Texas A & M, [Ma] and Utah [Wad], [WIL] or [AERE].

Vb. Tritium Bursts.

A few experimenters report occasional irreproducible amounts of excess tritium in D2O samples from their electrolytic cells after days of operation. This includes observations by Storms [St] at Los Alamos, and Fuller [Fu] and Scott [Sc] at ORNL. The ORNL experiments show single cases of excess tritium of short duration, after which a cell returns to background level. Storms reports excess tritium, 100 times background, in two cells out of 70. ~~(If we wait longer this number will grow.)~~

Vc. Closed Cells - Correlation with Excess Heat.

Four groups [McB,McC,Sc,Ma] have looked for tritium production in closed electrolytic cells. These experiments detect only the tritium from the electrolytic process except for that which may be contained in the Pd cathode. In general, the deuterium inventory in the cathode is negligible compared with the D2O. Only that tritium formed within the cathode and which remains there because of slow diffusion is unaccounted for. There is no electrolytic enrichment of the tritium in the make up D2O. In these experiments the total excess tritium formed in the D2O is less than 10**4 T

atoms/sec. If this tritium is produced by the D - D reaction, then the maximum excess power (cold fusion power) is 10**-5 milliwatts. In one experiment [Wad] in an open cell there was a heat burst of 35 watts for 90 minutes (187,000 joules). No excess tritium above the electrolytic enrichment was measured after the burst. Clearly the heat burst does not come from the D - D reaction.

Vd. High Levels of Tritium.

Two groups [Pa,Iy] find tritium at levels of 10**12 to 10**14 T atoms/ml D2O after periods of electrolysis of the order of hours. This amount of tritium cannot be produced by electrochemical enrichment with the D2O volume reductions reported. The results of the Bockris [Pa] group at Texas A & M for cells in which excess tritium was found are given in Table 1 of their paper. Excess tritium is not found in all of their cells. A listing of cells in which no excess tritium was found is given in their Table 4. The Bockris cells are 0.1 M in LiOD and have nickel anodes. They precipitate nickel oxide during the electrolysis; some nickel is also electroplated out on the palladium cathode. In one experiment, A8, the specific activity of the D2 gas produced by the electrolysis was measured. It is 100 times that of the electrolyte.

D2 (gas) containing tracer amounts of tritium and in equilibrium with D2O (liquid) has a specific activity that is lower by 0.6 than the D2O (liquid). If the tritium is formed during electrolysis, this result suggests that it is formed in the chemical species DT and that the tritium in the liquid D2O is the result of hot atom processes or slow isotopic exchange of the DT (gas) with D2O (liquid) [Bi2].

Wolf et al. [Wo] at Texas A & M have looked for neutron production in Bockris type cells. An upper limit to the production rate is 1 neutron/second, which is 10**-10 times that of the tritium production rates reported with similar cells by Packham et al.[Pa] This large discrepancy from the equal production rates for neutrons and tritons required by the branching ratio in the fusion reaction, discussed in section II, is inconsistent, by a factor of 10,000 to 100,000, even with the secondary neutrons that must accompany the tritons produced from nuclear fusion. Thus, the excess tritium found in the Bockris electrochemical cells cannot be the result of nuclear fusion in the cell.

The most extensive and systematic search for tritium in the electrolysis of D2O with Pd cathodes has been carried out by Martin[Ma] at Texas A & M. He has used both open and closed cells. His cathodes come from either Johnson & Mathey, a major supplier, or Hoover and Strong, who supplied the cathodes to the Bockris [Pa] group. He has operated cells with Pt, Ni wire and Ni gauze (obtained from Bockris) anodes. In none of his cells does he find any excess tritium beyond that expected from electrolytic enrichment. Nor does he find any neutrons. Two of his cells produced excess heat but no tritium. In short, he has been unable to reproduce the results of the Bockris group.

The BARC [Iy] group have found amounts of tritium comparable to the Bockris group in the D2O electrolyte from cells in which electrolysis was carried out for a few days with currents varying between 1 to 100 amperes. There is again a factor of 1000 internal inconsistency between the measured neutron yields and the neutrons that have to be there if this tritium was produced by fusion -- even if one assumes a drastic modification of the branching ratio in the D + D reaction.

The experiments to date include many with null results. The few

experiments in which excess tritium is reported have not been reproducible by other groups. These measurements also contain a serious internal inconsistency, in that the ratio of measured neutrons to tritium is smaller by orders of magnitude than what is consistent with a fusion process. Additional investigations are desirable to clarify the origin of the excess tritium that is occasionally observed.

VI. UNCONVENTIONAL EXPLANATIONS

VIa. D - D Reactions.

The data on fusion products, even where positive results are reported, give rates far below those that would be expected from the levels of heat reported in some electrolysis experiments. Some proposals invoke mechanisms where the reaction heat from the D + D --> 4He process would go entirely into lattice heat, rather than a photon [Wal,Ha]. Analogies have been made with the internal conversion process, and with the Mossbauer effect. Neither of these analogies is applicable to 4He.

Internal conversion allows an atomic electron of an excited nucleus to carry off the reaction instead of a photon. This process is understood quantitatively -- it is dominant in heavy atoms with tightly bound inner electrons and for low energy (less than 1 MeV) photons. In helium the atomic electrons are loosely bound and the photon is 23.8 MeV -- there can not be any appreciable coupling between the photon and the atomic electrons, and internal conversion or any related process cannot take place at anywhere near the rate that would be required. The proposal of Walling and Simons invokes enhancement of internal conversion by electrons of high effective mass appropriate to the solid; as we have discussed above, such band structure effects can in no way play the role of real high-mass electrons either in screening at sub-atomic distances or in the internal conversion process at MeV energies. Furthermore, although Walling initially reported 4He in appropriate amount to explain claims of excess heat, this result was due to atmospheric contamination.

In the Mossbauer effect the momentum of a very low energy (below 100 keV) photon is taken up by the entire lattice in a coherent mode, but not its energy. The process cannnot be relevant to the present process.

More generally, there are numerous reactions analogous to the D + D fusion process, in which gamma rays of comparable energy are emitted from low-energy nuclear reactions (thermal-neutron capture gamma rays). The cross sections for capture have been studied carefully and quantitatively; they are essential to the operation of fission reactors. If there were any anomalous processes in which ~~the energy of~~ a capture gamma ray ~~were converted~~ into lattice heat, this would have almost certainly been noticed as a discrepancy in cross sections with major implications for the operation of reactors. After four decades of extensive study of the processes relevant to the operation of fission reactors the possibility is remote that an entirely new process, that could dominate these nuclear reactions, would have remained hidden.

VIb. Other Fusion Reactions.

In addition to the D - D and p - D reactions discussed thus far, there are several other nuclear reactions that would be substantially exothermic if they could take place at a reasonable rate at low energy. Among these are deuterons fusing with 6Li, 7Li, 16O, as well as various Pd isotopes. The reaction rates for these processes are again governed by the

Coulomb barrier and for fusion at low temperatures this becomes even more overwhelming than for D + D. The process on Li isotopes, where the nuclear charge is three, is relatively the most favorable, but even these would give fusion rates that are enormously suppressed even in comparison with that for the D + D reaction; the rates are some forty orders of magnitude slower. The D + 6Li and p + 7Li reactions would not produce neutrons or direct gamma rays -- all the energy would be in alpha particles (4He nuclei), but these in turn would cause Coulomb excitation of the Pd. No such gammas have been seen.

VII. SEARCH FOR PRODUCTS OF COLD FUSION IN THE EARTH

Products of low-level cold fusion have been inferred to be produced by natural geologic processes [Jo, Jo1]. The 3He:4He ratio is anomalously high in volatiles from deep-source volcanoes such as Hawaii, Iceland, and Yellowstone [Cr,Ku,Mam]; anomalous T is also suggested by fragmentary data [Os,Jo2], and production of other radiogenic products such as 36Cl have been predicted [Ky]. Although the high 3He values have previously been considered relict from early earth processes, presence of anomalous T or 36Cl (beyond that due to bomb tests) would be definitive evidence of natural cold fusion at depth within the earth. Implications would be major for geophysical problems such as heat-flow modelling, element-distribution with depth, and composition of the Earth's core.

Although some isotope geochemists see no evidence for naturally occurring cold fusion [Cr1], several government and university labs are searching for evidence of such fusion processes as recorded by volcanic volatiles [Jo2,Ky,Go,Loc,Qu] independently of laboratory fusion experiments, such geologic studies could add much to understanding of the behavior of volcanic volatiles. No rigorous results are yet available, but experiments proposed or underway at Brigham Young, Los Alamos, Lawrence Livermore, New Mexico Tech, and the U.S. Geological Survey (Denver) should yield data within 6 months to 1 year.

New Energy Times Archive

VIII. SUMMARY

Careful experiments have been carried out to search for the expected products of cold fusion. None have seen these products within many orders of magnitude of the level that would be expected from the heat production reported in electrolysis. Some experiments report neutrons or tritium at a much lower level -- however, the rates of these two fusion products (measured in the same experiments) are inconsistent with each other, again by large factors. In particular, reported tritium production is accompanied neither by the one 2.45- MeV neutron per T observed in all other low-energy D - D fusion, nor by the 10**-5 14-MeV neutron per T that would be produced by the 1.01-MeV T itself in the D - rich experimental ~~timetable-neutron~~ environment.

The neutron bursts reported in some experiments are not reproducible by other experimenters, or even by those who report them. While some mechanism might produce small bursts of hot fusion (e.g. high voltage internal sparks associated with fracture of the material at certain temperatures), the present experimental evidence is not readily reproducible, and even if real, the phenomenon does not appear to be related to "cold fusion" as postulated in the heat production experiments. If there were such a process as room temperature fusion, it would require

(a) the circumvention of fundamental quantum mechanical principles, which have been ~~carefully~~ tested against measurements of barrier penetration (such as the systematics of spontaneous fission and alpha radioactivity

lifetimes and those of nuclear cross sections),

(b) drastic modifications of branching ratios in the D + D reaction, and

(c) the invention of a new nuclear reaction process.

TABLE I. SOME COLD FUSION NEUTRON RATES

Authors	Reference	Neutrons per DD pair per sec[a]	Yield Normalized to Jones et al. [Jo] neutrons[b]
Jones et al.	[Jo]	10-23	1
Broer et al.	[Br]	< 2.2x10-24	< 0.2
Williams et al.	[Wi]		< 0.2
Lewis et al.	[Le]	< 1.5x10-24	< .15
Alber et al.	[Alb]	< 5x10-25	< 0.05
Gai et al.	[Ga]	< 2x10-25	< 0.02
Schriber et al.	[Schr]		< 0.02
Kashy et al.	[Ka]	< 10-25	< 0.01
De Clais et al.	[DeCl]		< 0.01 < 0.001

a assuming that neutrons are produced throughout the volume of Pd.

b for comparison one watt of heat production by D - D fusion would correspond to 0.9x1012 in these units.

TABLE II. SOME COLD FUSION FAST CHARGED PARTICLE RATES

Authors	Reference	Protons per DD pair per sec[a]	Yield Normalized to Jones et al. [Jo] neutrons[b]
Jones et al.	[Jo]	~~1x10-23~~	1.0
Rehm et al.	[Reh]	< 4x10-23	< 4

New Energy Times Archive

Schrieder et al.	[Schr]	< 3.1x10-24	< 0.31c
Sundquist et al.	[Su]	< 2x10-24	< 0.2
Ziegler et al.	[Zi]	< 1.2x10-24	< 0.12c
Porter et al.	[Po]	< 6.7x10-25	< 0.07
Price et al.	[Pr]	< 8.3x10-26	< 0.008

a assuming that particles are produced throughout the volume of Pd.

b for comparison one watt of heat production by D - D fusion would correspond to 0.9x10^12 in these units.

c 6. Rehm et al comment that the choice of the low-energy cutoff (e.g. 1 MeV in Ref. [Zi]) restricts the emission angle of the protons with respect to the foil to a small cone representing only a few of the total solid angle. This effect seems to have been neglected in the efficiency calculations for the limits quoted by these authors.

New Energy Times Archive

REFERENCES

[Alb] Alber et al Z. Phys. A 333 319 (1989).

[Ald] F. T. Aldridge, R. J. Contolini, M. Y. Ishikawa and D. R. Slaughter, LLNL, communicated J. F. Holtzrichter to ERAB 8 September 1989.

[Bal] D. V. Balin et al. Phys. Letts 141B 173 (1989).

[Bar] C. A. Barnes et al. Phys. Letts. B197 315 (1987).

[Bi] J. Bigeleisen "Tritium Enrichment in the Electrolysis of D2O" Workshop on Cold Fusion Phenomena, Santa Fe, NM, 22-25 May, 1989.

[Bi2] J. Bigeleisen, letter of 26 August 1989 to J. O'M. Bockris.

[Br] Broer et al Phys. Rev. C preprint.

[Cr] H. Craig et al., Science, 214 (1981).

[Cr1] H. Craig, letter to P. Lipman, 28 Sept. (1989).

[Da] A. J. Davenport and H. S. Isaacs, BNL, communicated by P. Bond to ERAB 1 September 1989.

[DeCl] De Clais et al Sante Fe meeting

[DeN] A. De Ninno et al. Europh. Lett. 9 221 (1989).

[Er] J. Eridon, NRL, 17 August 1989 communication to ERAB.

[Fle] M. Fleischmann and S. Pons J. Electroanalytic Chem. 261 201 (1989).

[Fu] E. L. Fuller, ORNL Memo of 29 August 1989 to B. R. Appleton.

[Gai] M. Gai et al. Nature 340 29 (1989).

[Gar] R. L. Garwin, private communication.

[Go] F.E. Goff, letter to P. Lipman, 24 August (1989).

[Gr] L. R. Greenwood and C. A. Melendres, ANL, communicated to ERAB 23 August 1989.

[Ha] P. L. Hagelstein "On the Possibility of Coupling Nuclear Fusion Energy to Phonons." and "A Simple Model for Coherent Fusion in the Energy of a Lattice." preprints, August 1989.

[He] R. A. Henderson, et al. (Poster presented at Sante Fe Cold FusionMeeting), Lawrence Berkeley Laboratory Preprint LBL-2740, submitted to J. Fusion Energy.

[Iy] P. K. Iyengar, "Cold Fusion Results in the Bhabha Atomic Research Center (BARC) Experiments". Paper presented at the Fifth

International Conference of Emerging Nuclear Energy Systems (ICENES V). Karlsruhe, 3-6 July 1989.

Je R. J. Jensen, ADR:89-409, Report to ERAB 13 September 1989.

Jo Jones et al. (Nature 338, 737,1989).

Jo1 Jones et al., draft preprint (1989).

Jo2 Jones, priv. comm. to P. Lipman, 8 Sept. (1989).

Ka Kashy et al Phys. Rev. C 40 R1 (1989).

Ko S. E. Koonin and M. Nauenberg, Nature 339 690 (1989).

Kr A. Krauss et al. Nucl. Phys. A465 150 (1987), and references therein.

Ku M. Kurz et al., Earth Planet. Sci. Lett. 66, 388-406 (1983).

Ky P.R. Kyle, Priv. Comm. to P. Lipman, 16 August (1989).

Le N. Lewis et al Nature 340 525 (1989).

Le2 N. Lewis, California Institute of Technology Memo of 28 August 1989 to ERAB.

Loc J.P. Lockwood, letter to P. Lipman, 18 September (1989).

Lo G. R. Longhurst and A. J. Caffey, INEL, Communicated by S. C. T. Lien to ERAB 5 September 1989; G. R. Longhurst, T. J. Dolan and G. L. Henriksen, INEL, EGG-M-89203, 19 May 1989.

Mam Mamyrin and Tolstikhin, Helium Isotopes in Nature: Elsevier, Amsterdam (1984).

Ma C. R. Martin, Texas A & M, Letter of 11 September 1989 to ERAB.

McB P. Bond and N. P. Samios report to ERAB, 1 September 1989.

McC D. R. McCracken, et. al. J. of Fusion Energy, in press.

Me H. Menlove, preprint, LA-UR 89-1974 (Rev.). (Rev. 2) 09/18/89

Na A. Narath, Sandia Memo of 28 August 1989 to ERAB.

Os Ostlund and Mason, Atmospheric Tritium 1968-1984, Tritium Laboratory Rept. No. 14, Univ. Miami, Miama, Florida.

Pa N. J. C. Packham, K. L. Wolf, J. C. Wass, R. C. Kainthla, and J. O'M. Bockris, J. Electroanalytical Chem., in press.

Pe R. D. Petrasso et al. Nature 339 (183) 1989; ibid 667 (1989).

Por Porter et al. ("Search for Energetic Charged Particle Emission from Deuterated Ti and Pd Foils, J. Fusion Technology, submitted 7-15-89); LBL preprint 27523.

Pr Price et al. ("Search for Energetic Charged Particle Emission from Deuterated Ti and Pd Foils", Phys. Rev. Lett., submitted 7-14-89)

Qu J. Quick, priv. comm. to P. Lipman, 5 July (1989).

Ra H. W. Randolph, SRL-ELC-89007, 31.

Reh Rehm et al. preprint.

Red L. Redey, K. Myles, D. Dees, M. Krumpelt and D. R. Vissers, ANL, communicated by A. Schriesheim to ERAB 11 August 1989.

Sa Sandia

Schr Schriber et al Fusion Tech. preprint.

Sc C. D. Scott, ORNL Memo of 29 August 1989 to B. R. Appleton.

Su Sundqvist et al. Uppsala University, Sweden, preprint of ms accepted for publication in Physica Scripta, May 15, 1989.

Wad M. E. Wadsworth, Univ. of Utah, Letter of 6 September 1989 to ERAB.

Wal C. Walling, verbal report at the April 1989 meeting of the Nat. Ac. of Sc.; C. Walling and J. Simons J. Phys. Chem. 93 4693 (1989).

Wi Williams et al preprint.

Wi2 N. P. Samios report to ERAB, 18 September 1989.

Wil or AERE D. E. Williams, et al., Harwell Laboratory, UK Atomic Energy Authority.

New Energy Times Archive

Preprint 19 September 1989 "Studies of "Cold Fusion" Electrolytic Cells".

[Wo] K. L. Wolf, N. Packham, J. Schoemaker, F. Cheng and D. Lawson. Proc. of the Santa Fe Cold Fusion Workshop, in press.

[Zi] Ziegler et al. Phys. Rev. Lett. 62, 2929 (1989).

APPENDIX A

NEUTRON DETECTION.

Neutrons from dd fusion can be detected after either at their initial energy in the MeV range as "fast" neutrons, or their enegy has been "moderated" by sharing it in successive collisions with light material -- particularly hydrogen. Fast neutrons can be detected by photomultiplier tubes viewing the proton recoil in plastic or liquid scintillation material. Slow neutrons (those that have lost almost all their kinetic energy and are in thermal equilibrium at room temperature) are conventionally detected by the charged particles produced when the neutron is captured with high probability in the nucleus of an atom of 10B (producing an alpha particle), or in a 3He nucleus, producing a recoil proton. A noble gas, 3He is used in the form of a proportional counter, while boron can be used either in the form of BF3 proportional counters or in the solid form, with the boron immersed in plastic or inorganic scintillator viewed by a photomultiplier.

Additionally, neutrons can be detected after moderation by their capture in some material of very high capture cross section (such as cadmium Cd), which produces several gamma rays that may, in turn, be detected by a photomultiplier viewing a scintillation detector. Similarly, neutrons moderated in water are almost entirely captured on the protons ("radiative capture"), giving rise to a deuteron plus a gamma ray with 2.2 MeV.

Finally, moderated neutrons may be captured in a trace element in the moderator (silver is a detector of choice) to produce a radioactive material that can be transported away from the experimental apparatus and counted separately with high efficiency at low background. The emitted radiation is typically a beta ray (negative electron), or a characteristic gamma ray following the beta decay. Of course, the world has enormous experience since the 1930s in detecting neutrons and in detecting neutrons from the D + D fusion reaction.

New Energy Times Archive

APPENDIX B

CONSIDERATIONS IN TRITIUM CONCENTRATIONS.

Tritium is produced in the atmosphere by cosmic ray bombardment. Most of such tritium ends up in the oceans and in rivers. The "natural" abundance of tritium varies widely and was greatly increased by atmospheric testing of thermonuclear weapons in the '50s and in the early '60s. The order of magnitude of tritium in ordinary water is T/H - 10-18 (1 TU). Sources vary from 1 to 200 TU. The production of heavy water from ordinary water is even more efficient in the enrichment of tritium than deuterium from the feed material. Most of the heavy water currently available is produced by the H2S - H2O dual temperature exchange process (GS process). The tritium content of fresh heavy water produced by the GS process is 68 dpm/ml D2O/TU feed. Processes that are more efficient than the GS process in heavy isotope enrichment will have a minimum tritium specific activity of 50 dpm/ml D2O/TU feed. Heavy water currently being sold on the open market has a specific activity in the range 120 - 180 dpm/ml D2O. There are sources of D2O with

specific activity as high as 10⁴ dpm/ml.

Most of the work done to date on the search for tritium produced in the electrolysis of D2O in cells with palladium cathodes has been done in open cells. The measurements are frequently limited to assays of the specific activities of the starting D2O and the electrolyte after electrolysis. In general, there have been periodic additions of D2O to replace the D2O decomposed to form palladium hydride and D2(gas). To determine how much tritium, if any, has been produced requires a complete inventory of the tritium at the beginning and end of the experiment. From the data on the current and on the duration of the electrolysis it is possible to estimate the amount of D2O which has been electrolyzed. Electrolysis will enrich the tritium in the D2O of an electrolytic cell. The amount of enrichment is primarily a function of the amount of water electrolyzed for a given type of cathode. It can reach a factor of 5 when 95% of the initial charge of water is electrolyzed. Thus a careful analysis of an electrolytic experiment must be carried out if one is to interpret specific activities of tritium after electrolysis, below 1000 dpm/ml of D2O, as anything other than electrolytic enrichment [Bi].

New Energy Times Archive

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 586-5444

19 OCT 89 13:59 R.L. GARWIN-

October 17, 1989

To: Members of the Cold Fusion Panel

Subject: Draft of Final Report and October 30-31 Meeting

As discussed at our October 13 meeting, all working group coordinators are asked to have their sections to me no later than COB Tuesday, October 24. With your section please also include your computer disc with that material on it. Maggie uses Word Perfect 5.0 and an IBM PC XT with 3 1/2 x 3 1/2" hard discs. It is compatible with almost any language or machine so even if you do not use the same equipment, send the disc anyway and we will transfer the information.

I will express mail to each of you on October 25 a complete draft of the report. It will be sent to you at your regular mailing address unless you instruct me otherwise.

The meeting will begin at 8:30 a.m. on October 30 in Room 4A-110 of the Forrestal Building and will run until no later than 9:00 p.m. Lunch and dinner will be in Room 6A-110 (sandwiches only). On Tuesday we will resume at 8:30 a.m. and will adjourn at noon or shortly thereafter. Coffee will be available each day at 8:00 a.m.

For those who were not at the October 13 meeting, copies of the section drafts are enclosed. As a reminder, working group coordinators and members are as follows:

Introduction: Fowler (Coordinator), Gavin, Huizenga, and Koonin.

Calorimetry: Bard (Coordinator), Faulkner, Happer, Miller, and Wrighton.

Materials: Birnbaum (Coordinator), Boudart, Dresselhaus, Nelson, and Stein.

Fusion Products: Schiffer (Coordinator), Bigeleisen, Garwin, Hoffman, Koonin and Lipman.

Conclusions and Recommendations: Huizenga (Coordinator), Bard, Birnbaum, Callis, Garwin, and Schiffer.

William L. Woodard

Enclosures (for Messrs. Boudart, Faulkner, Gavin, Koonin, Nelson, Ramsey, Schiffer and Wrighton only)

101789.WLW

New Energy Times Archives

Date: 17-OCT-1989 19:50:50.02
From: "SCHIFFER@ANLPHY (312)972-4066 FAX:972-3903" <SCHIFFER@ANLPHY>
To: RLG2@YKTVMV.BITNET
Subject: RE: 10/13/89 comments on our section.
X-ANJE-To: GATEWAY::"RLG2@YKTVMV",SCHIFFER

Dear Dick,

I received the annotated copy late this afternoon. Many thanks for your help on this. Most of the points will be incorporated -- I want to modify a few.

I would appreciate it your continued help in getting the final product. There were some points in your notes that I could not follow. Also, your assistance with changes for the neutron section would be very helpful.

I annotated your list here in capitals after deleting the points that are clear.

On the address you have for me, note that I wear at least two hats -- my editorship for Physics Letters is only pertinent to editorial correspondence. But never mind if it is too complicated for your address file to recognize me under two guises.

Thanks again for your help,

John

Page 5.2 Here it was suggested that we should include the summary conclusion from the top of page 8.
DO NOT UNDERSTAND

Page 5.6 As indicated on the Lipman draft, this paragraph should go at the bottom of page one. There was strong sentiment (and agreement) that we should also refer to the "latest data submissions" and to the "routine reports from the national labs", all of which are available to the public in the DOE reading room.
DO NOT UNDERSTAND WHAT IS TO BE DONE ABOUT SECOND PART OF PARAGRAPH.

COULD YOU PLEASE HANDLE THE CHANGES ON PAGES 6 - 8? I DO NOT SEE AN EASY WAY AROUND COMMENT 7.9 (TOO MANY REPETITIONS OF SECONDARY NEUTRONS), SO UNLESS YOU HAVE A GOOD IDEA, SUGGEST THAT WE LEAVE IT AS IT IS. IF YOU WANT ME TO DO ANY OF THESE PLEASE LET ME KNOW.

Page 9.3 It was recommended that we cite the Harwell results here. Also on page 9.7 under "Null Experiments."
WILL LOOK INTO THIS -- BIGELEISEN IS AWAY -- HE SENT ME SOME CHANGES BUT NOT THIS.

Page 11.1 In regard to "In short, he has been unable to reproduce the results of the Bockris group." Alan Bard said at the meeting (reading from his notebook) that on 10/06/89 one out of 14 Wolf cells showed 2x10**5bdpm/ml (and 10**6 in the off gas), but no neutrons."
DO NOT UNDERSTAND REFERENCE TO WOLF CELLS. THE PARAGRAPH IS ABOUT MARTIN. AGAIN BIGELEISEN HAD NO CHANGES.

New Energy Times Archive

Page 11.2 Regarding BARC, I enclose a draft comprehensive report of 10/01/89, which I received from P.K. Iyengar via Martin Blume. Unfortunately, the autoradiography section is missing, so I have sent the enclosed letter to P.K. Iyengar.
I ASSUME NO CHANGES ON THIS POINT

Page 14.0 Regarding the Fleischmann entry, we believe it should be removed from the Table. John Huizenga also points out that that the 1:1 mixture gives 0.9x10**12 neutrons per watt rather than the 3x10**12 shown in the Table. In this Table, we believe that the neutron numbers should be reported (FLE 1989a), and in a footnote we should refer to the discrepancy between the neutron numbers and the heat.
WILL CHANGE THE FOOTNOTES BUT NOT CERTAIN WHAT NEUTRON NUMBERS ARE MEANT. COULD YOU CLARIFY PLEASE?

The footnote (a) for Table I should read "... throughout the volume of Pd." Probably there should be a second footnote (b) "At Santa Fe, Jones et al reported a factor seven lower neutron numbers," (asserted by John Huizenga).
HUIZENGA MENTIONED THIS TO ME AS WELL -- BUT I HAVE NO WRITTEN RECORD OF IT AND WOULD PREFER TO STAY WITH WHAT IS ON PAPER, OTHERWISE ALL ARE CONFUSED.

It was also recommended that we include the Michael Solomon results on the Pons cells-- both electronics and Lexan.
FINE, BUT DO WE HAVE THE INFORMATION?

Page 7.4 It was recommended that in conjunction with the work of Menlove, we include the criticisms by Gai. Furthermore, we should refer to the Harwell publication regarding T, He-3, He-4, and neutrons.
THE COMMENTS GAI MADE TO ME, WHICH I ASSUME WERE SIMILAR TO THE ONES THAT WERE MENTIONED, WERE NOT VERY SUBSTANTIVE AND SOME (SUCH AS NEUTRON BURSTS PRODUCED BY COSMIC RAYS IN THE DEUTERIUM, WERE QUANTITATIVELY WRONG) -- HE HAD NOT TALKED TO MENLOVE RECENTLY. I ASSUME YOU WILL, AS INDICATED IN YOUR NOTE.

John Huizenga reported at the meeting that he had received a letter from Willis Lamb reporting that Lamb had found a "serious error" in the reaction rates calculated by Lamb and Parmenter. The papers are to be published soon in PNAS, so Lamb will publish an Erratum.
NOT CLEAR HOW WE SHOULD CITE THIS

New Energy Times Archive

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 586-5444

17 OCT 89 14:64 R.L. GARWIN-

October 17, 1989

To: Members of the Cold Fusion Panel

Subject: Draft of Final Report and October 30-31 Meeting

As discussed at our October 13 meeting, all working group coordinators are asked to have their sections to me no later than COB Tuesday, October 24. With your section please also include your computer disc with that material on it. Maggie uses Word Perfect 5.0 and an IBM PC XT with 3 1/2 x 3 1/2" hard discs. It is compatible with almost any language or machine so even if you do not use the same equipment, send the disc anyway and we will transfer the information.

I will express mail to each of you on October 25 a complete draft of the report. It will be sent to you at your regular mailing address unless you instruct me otherwise.

The meeting will begin at 8:30 a.m. on October 30 in Room 4A-110 of the Forrestal Building and will run until no later than 9:00 p.m. Lunch and dinner will be in Room 6A-110 (sandwiches only). On Tuesday we will resume at 8:30 a.m. and will adjourn at noon or shortly thereafter. Coffee will be available each day at 8:00 a.m.

For those who were not at the October 13 meeting, copies of the section drafts are enclosed. As a reminder, working group coordinators and members are as follows:

Introduction: Fowler (Coordinator), Gavin, Huizenga, and Koonin.

Calorimetry: Bard (Coordinator), Faulkner, Happer, Miller, and Wrighton

Materials: Birnbaum (Coordinator), Boudart, Dresselhaus, Nelson, and Stein

Fusion Products: Schiffer (Coordinator), Bigeleisen, Garwin, Hoffman, Koonin and Lipman.

Conclusions and Recommendations: Huizenga (Coordinator), Bard, Birnbaum, Callis, Garwin, and Schiffer.

William L. Woodard

Enclosures (for Messrs. Boudart, Faulkner, Gavin, Koonin, Nelson, Ramsey, Schiffer and Wrighton only)

New Energy Times Archive

Larry R. Faulkner
University of Illinois
Urbana, IL 61801
FAX (217) 244-8068

T. Kenneth Fowler
University of California
Berkeley, CA 94720
FAX (415) 643-9685

Richard L. Garwin
IBM Corporation
Yorktown Heights, NY 10598
FAX (914) 945-2141

Joseph Gavin, Jr.
Grumman Corporation
Bethpage, NY 11714
FAX (516) 575-3631

William Happer, Jr.
Mitre Corporation
La Jolla, CA 92038
FAX (609) 258-1297

Darleane C. Hoffman
Lawrence Berkeley Laboratory
Berkeley, CA 94720
FAX (415) 486-4515

Steven E. Koonin
CALTECH
Pasadena, CA 91125
FAX (818) 564-8708

Peter Lipman
US Geological Survey
Denver, CO 80225
FAX (303) 236-5448

Barry Miller
AT&T Bell Laboratories
Murray Hill, NJ 07974
FAX (201) 582-3609

David Nelson
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

John P. Schiffer
Argonne National Laboratory
Argonne, IL 90439
FAX (312) 972-3903

Dale Stein
Michigan Technology University
Houghton, MI 49931
FAX (906) 487-2398

Mark Wrighton
MIT, Building 6, Room 335
Cambridge, MA 02139
FAX (617) 258-7652

New Energy Times Archive

0001-P01

DOE F 1325.7
(3-83)

Exception to SF 14, Approved by NARS, June 1978

Unclassified

1. INSERT ABOVE, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY

2. MESSAGE CONTAINS WEAPON DATA?
("X" appropriate box. Message Center will not transmit message unless one box is marked.)
☐ YES ☒ NO

U.S. DEPARTMENT OF ENERGY
TELECOMMUNICATION MESSAGE
(See reverse side for instructions.)

1123

3. USE WHEN REQUIRED
THIS DOCUMENT CONSISTS OF 23 PAGES
NO. ____ OF ____ COPIES, SERIES ____

4. PRECEDENCE DESIGNATION ("X" appropriate box):

	FOR NORMAL USE		EMERGENCY USE ONLY	
ACTION:	☒ Routine	☐ Priority	☐ Immediate	☐ FLASH
INFO:	☐ (6 Hrs.)	☐ (3 Hrs.)	☐ (30 Mins.)	☐ (ASAP)

5. TYPE OF MESSAGE
("X" appropriate box)
☐ Single Address
☒ Multiple Address
☐ Title Address
☐ Book Message

FOR COMMUNICATION CENTER USE
MESSAGE IDENTIFICATION
NR: DTG: Z

6. FROM Bill Woodard
Forrestal

7. OFFICIAL BUSINESS
Bill Woodard
(Signature of authorizing official)
TIME (A.M. / P.M.)

8. DATE 10/17/89

9. TO

John Huizenga, Co-Chairman
University of Rochester
Rochester, NY 14627
FAX (716) 473-6889

Howard K. Birnbaum
University of Illinois
Urbana, IL 61801
FAX (217) 244-2278

Norman Ramsey, Co-Chairman
Harvard University
Cambridge, MA 02138
FAX (617) 495-0416

Michel Boudart
Stanford University
Stanford, CA 94305
FAX (415) 725-7294

Allen J. Bard
University of Texas
Austin, TX 78712
FAX (512) 471-8696

Clayton F. Callis
American Chemical Society
St. Louis, MO 63131
FAX (314) 569-3712

Jacob Bigeleisen
SUNY, Stony Brook
St. James, NY 11780
FAX (516) 632-7960

*Mildred Dresselhaus
MIT, Room 13-3005
Cambridge, MA 02139
FAX (617) 253-2112

BE BRIEF ELIMINATE UNNECESSARY WORDS

COMMUNICATION CENTER USE ONLY

New Energy Times Archive

10. ORIGINATOR *(On separate lines, enter Name, Routing Symbol, & Tel. No.)*
Bill Woodard
EE-6
6-5444

11. DERIVATIVELY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to ...
Derivative Classifier: (Name) ____
(Title) ____
Declassify on: (Date or Event/OADR) ____
Derivatively Classified by: (Guide or Source Document) ____

12. ORIGINALLY CLASSIFIED NSI
NATIONAL SECURITY INFORMATION
Unauthorized Disclosure subject to ...
Originally Classified by: (Name) ____
(Title) ____
Declassify on: ____
(Date or Event/OADR)

13. ☐ RESTRICTED DATA
This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Unauthorized disclosure subject to Administrative and Criminal Sanctions.
DERIVATIVE CLASSIFIER ____
(Name and Title)

14. ☐ FORMERLY RESTRICTED DATA
Unauthorized disclosure subject to Administrative and Criminal Sanctions. Handle as Restricted Data in Foreign Dissemination Section 144.b Atomic Energy Act, 1954
DERIVATIVE CLASSIFIER ____
(Name and Title)

15. INSERT BELOW, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY
Unclassified

Suspense

Richard L. Garwin
IBM Research Division
Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598
(914) 945-2555
FAX: (914) 945-2141, Telex: 137456 IBMRESRCH YKHG UD,
BITNET: RLG2 at IBM.COM

October 16, 1989
(Via FAX to (91-22) 204-8476)

Dr. P.K. Iyengar
Bhabha Atomic Research Centre
Trombay, Bombay 400 085
INDIA

Dear Dr. Iyengar:

Thank you much for our telephone conversations when you were at Brookhaven 10/09/89. As you know, we are working hard to prepare our final report on Cold Nuclear Fusion, and your draft comprehensive report 10/01/89 (which I received from Dr. Blume) will be helpful to me. Paper B3, however, is not included in the compilation, and we are most interested in it. If you could send it to me by FAX at the above number, I would be most grateful.

I promised to find for you the low-energy cross section data for D-D reactions. One reference is A. Krauss, et al, Nuclear Physics A465,150 (1987); we don't have this in our library, but I'll send you the relevant page when I find it. I hope this is helpful to you.

I don't know whether you have seen The Salt Lake Tribune article of 09/26/89, "Utah Institute Fails to Duplicate Fusion Tests." In it, Tim Fitzpatrick quotes Hugo Rossi, Director of the Utah National Cold Fusion Institute, as saying that the Institute's more than 20 electrochemical cells "have produced no excess heat and no fusion products such as neutrons or tritium."

Sincerely yours,

Richard L. Garwin

Encl:
09/26/89 "Utah Institute Fails to Duplicate Fusion Tests," by Tim Fitzpatrick in The Salt Lake Tribune. (092689..TF)

RLG:jah:289%PKI:101689.PKI

New Energy Times Archive

.qq
&EXIT

THIS FILE HAS BEEN RECEIVED FROM BITNET

The file may be executable. Before removing this header you must understand what the code will do. You must also have the appropriate intellectual property agreements in place before receiving the code into IBM.

If you have any questions, contact your manager.

The contents of the file has been shifted right by one character.
Filename=(none) Filetype=(none) RECFM=F LRECL=80 Records=45
The file received from the BITNET gateway begins below the next line.

Date: Mon, 16 Oct 89 12:01 EDT
From: JBIGELEISEN@SBCCMAIL.BITNET
Subject: Corrections to 10 October Draft
To: RLG2@YKTVMV.BITNET
X-VMS-To: in%"RLG2@YKTVMV.BITNET"

State University of New York at Stony Brook
Stony Brook, NY 11794-3400

Jacob Bigeleisen
Professor
Chemistry
516-632-7905
16-Oct-1989 11:46am EDT

FROM: JBIGELEISEN
TO: Remote Addressee (_SCHIFFER@ANLPHY.BITNET)
TO: Remote Addressee (_RLG2@YKTVMV.BITNET)
TO: Remote Addressee (_HUIZENGA@UORCHEM.BITNET)

SUBJECT: Corrections to 10 October Draft

These are the corrections and additions to the 10 October draft on Fusion Products.

1. Page 9 Null Experiments. Add [WIL] or [AERE] In the list of references identify [WIL] or [AERE] D. E. Williams, et. al. Harwell Laboratory, UK Atomic Energy Authority. Preprint 19 September 1989 "Studies of "Cold Fusion" Electrolytic Cells".
2. Page 9 Vb. last line change to read .."cells out of 70". (If we wait longer this number will grow)

The following changes should be made in the references now that we have documentation to replace all those JB memoranda to file:

a. [Bi2] there is no further documentation on this. The reference can stay or be eliminated entirely without changing the text.
b. [Je] change to R.J. Jensen, ADR:89-409, Report to ERAB 13 September 1989
c. [McB] change to P. Bond and N.P. Samios reprt to ERAB, 1 September 1989. (do not change symbol).
d. [Wi2] change to N> P> Samios report to ERAB, 18 September 1989. (do not change symbol).

This completes the revisions I was requested to make at the 13 October meeting.

I will be on travel for the next two weeks, but will be at what I hope will be our final meeting on 30 - 31 October.

JAKE

New Energy Times Archive

Date: 27 October 1989, 11:37:24 EDT
From: (R.L.Garwin (914) 945-2555) RLG2 at YKTVMV
IBM Fellow and Science Advisor to the Director of Research
P.O. Box 218
Yorktown Hts, NY 10598
To: SCHIFFER at ANLPHY
Subject: Minor comments on Draft of 10/26/89.
Reply-To: RLG2 at WATSON

John, thanks very much for all of the inspired effort. This will be repaid now by unrelieved criticism (but all minor).

1. On your page 6.2 (two-tenths of the way down your numbered page 6 (assuming the page numbers are at the top of the page),
**
Typical of the latter is work by the group at Sandia National
**
This would better be rendered here,
Typical of experiments with greater sensitivity is work by the gr...
***

2. On page 7.3,
**
verification, both at Frascati and elsewhere. A recent private
**
would better be rendered:
verification, both at Frascati and elsewhere. A recent personal
***

3. On page 8.1,
**
who accelarated singly charged clusters of heavy ice, on the order of 100 molecules, to voltages up to 325 keV. They obtained some evidence of the p
**
would better be:
who accelerated singly charged clusters of heavy ice, on the order of 100 molecules, to voltages up to 325 keV. They obtained evidence of the p
***

4. Page 9.4,
**
per second is much below the average low rate inferred from the neutron
**
would better be:

per second is much below the average rate inferred from the neutron
***

5. Page 10.7,
**
two cells out of 70. Vc. Closed Cells - Correlation with Excess Heat.
**
(A new line should begin with the "Vc...)

Sorry I can't be with you. I will send John Huizenga a couple of draft conclusions in the next hour or so.

Dick Garwin

New Energy Times Archive

Date: 26-OCT-1989 19:03:26.34
From: "SCHIFFER@ANLPHY (312)972-4066 FAX:972-3903" <SCHIFFER@ANLPHY>
To: rlg2@yktvmv.BITNET
Subject: latest draft
X-ANJE-To: GARWIN, HOFFMAN, KOONIN, BIGELEISEN,SCHIFFER

Enclosed is the latest ~~graph~~ draft incorporating editing by Garwin and minor changes, mostly in the neutron section. References have been improved. Mention is made now of some of the material Jones sent (e.g. Grand Sasso), of the Russian experiments, and of the BNL cluster work. If you cannot come to the meeting next week please send me comments by bitnet before Sunday.

Hope we are done with this!! John S.

C.2
~~9.2~~ 7.3
8.1
9.4
10.7

Draft - Oct. 26, 1989

FUSION PRODUCTS

New Energy Times Archive

I. INTRODUCTION

The nuclear fusion of deuterium has been studied intensively for over 40 years. The reaction between two low energy deuterium nuclei can proceed in three ways:

(a) D + D --> 3He (0.82 MeV) + n (2.45 MeV)

(b) D + D --> T (1.01 MeV) + p (3.03 MeV)

(c) D + D --> 4He + gamma (23.847 MeV)

The reactions (a) and (b) have been studied down to deuteron energies of a few keV and the cross sections found to be equal to within 10%. In the interaction of deuteron beams with heavy ice or metal deuteride targets, almost one 2.45 MeV neutron is produced (with an accompanying 3He) for every triton (with an accompanying proton). This near-equality of neutron and proton branches of the D + D reaction, shown in figure 1, is a reflection of the basic symmetry of nuclear forces between proton and neutron, disturbed only slightly at the MeV energies of the emerging particles by the Coulomb interaction, which is not symmetrical between proton and neutron. The cross section for reaction (c) is on the order of 10**7 lower than the first two.

All nuclear reactions at low energies between two deuterons are retarded by the Coulomb repulsion between the positively charged nuclei -- the penetration of the repulsive Coulomb barrier changes rapidly with bombarding energy: for instance the measured cross section for reaction (b) changes from 0.2 microbarns at 2.7 keV to 35 millibarns at 100 keV. But the ratios for the three reactions appear to be constant below 100 keV.

Any fusion between deuterium nuclei must lead to detectable fusion products. For reaction (a) neutrons are the most easily detected product, by direct counting. For (b) the protons or tritons can be detected by direct counting, and the accumulated tritium could also be identified by its radioactivity, albeit with lower sensitivity for few-hour or few-day

experiments, in view of the 12-year half life of T. Neutron counting is perhaps again the most useful technique here, since neutrons must be produced by the energetic tritons interacting with deuterons in the material at the expected rate of 1 neutron for every 10,000 to 50,000 tritons. Reaction (c) leads to readily detectable high energy gamma rays and 4He; the latter may be identified by mass spectroscopic measurements, whose sensitivity is low -- though the 10**17 levels implied by 1 watt of heat should be readily observable.

In the following we summarize the experimental evidence on these fusion products. First we discuss the plausibility of reactions at room temperature and the issue of whether the constancy of the three reaction modes is a reasonable extrapolation to such low energies. Then the data on neutrons, charged particles, gamma rays and tritium are summarized. Finally, some comments are included on unconventional explanations, and geochemical evidence is summarized on proposed cold fusion in the interior of the earth.

New Energy Times Archive

We have used published material, where available, or material prepared for publication and presented at formal meetings or as preprints distributed without restriction as to citation. We Have also benefited from data submissions in response to panel questions and from routine reports from the national laboratories, all of which are available to the public in the DOE reading room. It is important to include not only positive results, that claim the detection of fusion products, but also the negative ones, that have attempted to replicate the experimental procedure of the former and failed to detect anything above background, at a level of sensitivity substantially better than the positive results.

II. THE REACTION PROCESS

Fusion reactions can occur only if during a nuclear collision the Coulomb barrier is surmounted or, at low energies, penetrated so that the nuclei approach each other within about 10**-12 cm. This distance is some 10000 times smaller than the typical separations of atoms in ordinary matter. The penetration of the barrier at low energies takes place through a well-understood quantum mechanical phenomenon called tunneling that allows fusion to occur in collisions far less violent than might be required otherwise.

In the thermonuclear fusion that occurs in stars and in laboratory "hot fusion" experiments, high temperatures (tens of millions of degrees or more) provide the violent collisions required to produce fusion. However, in the so-called cold fusion experiments, it is claimed that the

penetration of the barrier through quantum mechanical tunneling has somehow become so effective as to allow fusion to occur even at room temperatures. Further, some experimenters claim that the nuclear process is changed by an unspecified mechanism so as to alter dramatically the nature of the reaction products. Each of these claims must be understood as separate and equally surprising.

Some simple calculations illustrate how remarkable is the claim of fusion at room temperatures. The fusion rate for the two deuterium nuclei in a deuterium molecule (where they are even closer than they are when embedded in a metal) results in one fusion per year in a solar mass of deuterium. Further, the fusion of protons and deuterons is calculated to be 109 times faster than the D + D reaction claimed to have been observed (although it is still extraordinarily slow). No mechanism is known by which these rates could be enhanced by the 40-50 orders of magnitude required to agree with the reported observations.

One mechanism invoked for enhancing cold fusion rates is screening the electrostatid repulsion by "heavy" electrons. Endowing the electrons with a hypothetical mass would indeed enhance fusion rates sufficiently to agree with most cold fusion claims [Koo89]. It is also true that there are "heavy fermion" materials whose thermodynamic properties at very low temperatures are characteristic of quasiparticles with masses many times those of a free electron. However, this phenomenon is understood as involving long-wavelength excitations in which strong correlations "dress" electrons near the Fermi surface. As such, heavy fermions extend over many lattice sites. Because the tunnelling in nuclear fusion occurs at distances smaller than one lattice site, only the short-wavelength "bare" electron excitations are relevant for screening, and cannot enhance the fusion rate significantly.

New Energy Times Archive

IIa. The D + D Branching Ratios.

The relative rates of reactions (a), (b), and (c) are called the branching ratios and are a crucial issue in the discussion of some cold fusion claims. These reactions have been studied in laboratory experiments using accelerators for deuteron energies above a few keV [Kra87]; the smallness of both cross sections prevents reliable measurements at lower energies. The ratio between the two rates exhibits a weak energy dependence and is near 1.0 at the lowest energies as seen in figure 1. Data from muon-catalyzed D + D fusion [Bal84], which probes an even lower energy range, is still consistent with nearly equal rates.

A branching ratio of more than one million would be required to explain experiments that claim to observe high fusion rates (either through heat or tritium production) without a corresponding high neutron flux. As "cold fusion" is thought to occur at energies on the order of eV, this is not directly ruled out by the data discussed above. However, no mechanism is known for inducing such a rapid energy-dependence in the branching ratio. The Oppenheimer-Phillips process involving the Coulomb break-up of the deuteron has sometimes been invoked in this regard. However, this process is not effective at low energies in the D + D system.

IIb. The Gamma Branch.

Some researchers have hypothesized that the D + D --> 4He + gamma (23.847 MeV) reaction, which is ordinarily some 10**7 times weaker [Bar87] than reactions (a) and (b) in which two fragments are produced, somehow

dominates in cold fusion situations. To be consistent with the lack of neutrons, a very large enhancement of the gamma branch by a factor somewhere in excess of 10**13 would be required. We know of no way whereby the atomic or chemical environment can effect such an enhancement, as this ratio is set by phenomena on a length scale some 10**4 times smaller than the atomic scale.

Even if there were such an enhancement, the absence of observed high-energy electromagnetic radiation (photons, positrons, or fast electrons) rules out such a mechanism. While direct coupling to the lattice through unspecified mechanisms has been invoked to suppress such radiation, any such coupling must occur through the electromagnetic field and would result in some observable high-energy radiation.

IIc. The p + D Reaction.

It has been suggested that an alternative fusion process could be the reaction

p + D --> 3He + gamma (5.49 MeV)

for which the penetration factors are still overwhelmingly small at room temperature, but somewhat less so than for the D + D process [Koo89]. This reaction produces a readily observable gamma ray and if it is to account for 1 watt of heat, then it should also produce 3He in observable concentrations.

IId. Anticipated Secondary Yields from Fusion Products.

i) Neutrons from tritium. The tritons produced in reaction (b) have an energy of 1.01 MeV. This energy must be lost in the immediately surrounding material, which in an electrolytic cell is either the Pd electrode saturated with

deuterium, or heavy water. The tritons will therefore bombard the deuterium in the surrounding material. The T + D reaction is a rich source of 14-MeV neutrons, with a cross section that reaches 5 barns (i.e., 5x10**-24 cm2) at 0.12 MeV, then falls to about 0.7 barns at 0.5 MeV, and reaches slightly below 0.3 barns at 1 MeV. For the 1.01 MeV tritons from the D + D reaction an average cross section is about 1.2 barns. For tritons that are stopped in PdD this translates into a neutron yield between 1.5 and 2x10**-5 neutrons per triton; for tritons stopping in heavy water there are about 9x10**-5 per triton.

ii) Coulomb excitation of Pd by protons. The even Pd isotopes (104,106,108,110) with abundances of 11,27,26,12 % have first-excited 2+ states at 555, 512, 434, 374 keV and B(E2) values between 0.5 and 0.8 barns. The cross sections for Coulomb excitation are in the vicinity of 20 to 50 millibarns and thus the yields expected are 2 to 5x10**-6 per proton. In palladium the half thickness for absorption of these gamma rays is about 4 mm, in water it is several cm.

In terms of power, there must be about 10**8/sec secondary (14-MeV) neutrons per watt of fusion, even if direct neutron production is completely suppressed and all the reaction goes into tritium production. Under these conditions there must also be slightly under 10**7 secondary photons per second, of well defined energies, in the 500 keV range.

New Energy Times Archive

III. NEUTRONS

IIIa. Detection.

Neutrons are a major product of D + D fusion. Neutrons are convenient particles to detect, since they interact only with the nuclei of atoms and so can emerge from reaction vessels of substantial size unscathed and without having lost energy. Similarly, large counters can be used without the problem of thin entrance windows, since neutrons enter into the volume of the counter without difficulty. Some simple facts about neutron detection are summarized in Appendix A.

IIIb. Initial claims.

The University of Utah (UU) group in its initial publication [Fle89] claimed the detection of neutrons from D + D by virtue of the gamma ray emitted by the capture of the moderated neutron in the water bath surrounding the electrolytic cells. A narrow peak in the pulse-height spectrum from the NaI scintillator was published, narrower than is possible with this type of detector, and with internal inconsistencies in the energy scale as pointed out by a group at MIT [Pet89]. The photo peak at 2.2 MeV obtained at MIT from Cf spontaneous fission neutrons moderated in water and radiatively captured on protons is accompanied by other peaks from natural background that enable one to calibrate the energy. Successive interchange between UU and MIT groups in the scientific literature has demonstrated that the claimed detection of neutrons by the proton capture gamma ray at UU was an artifact of the experimental apparatus.

The original publication from Brigham Young University (BYU) [Jon89a] presented the detection of neutrons as the sole experimental evidence for the existence of cold nuclear fusion. The neutrons were detected in a two-stage neutron counter -- first by the proton recoil in organic scintillator, followed within a few tens of microseconds by a signal from the capture of the moderated neutron on boron viewed by the same photomultipliers. This double detection of

New Energy Times Archive

a single neutron serves substantially to reduce the ambient background due to gamma rays, although there remains background in the experiment due to gamma rays and to real neutrons from cosmic rays* and other sources. BYU has been working in collaboration with other groups, notably at LANL [Men89], and also with a group at Yale University. The original claim of neutron detection five standard deviations above the background is somewhat reduced in statistical strength if one considers the degrees of freedom that are fixed by the presentation of a peak in one of a number of experiments and at a particular energy, and also the possible fluctuation in the cosmic-ray neutron background; in fact, Sundqvist recalculates the BYU effect as 1.25 standard deviations. Ordinarily, however, such a result can be improved through improved shielding or by moving to an underground site. Another group at BYU [Pit89] electolyzed 3 M LiOD on Pd cathodes and detected about 2.1 x 10**-3 counts per second as compared to 1.2 x 10**-3 for light water cells.

Typical of ~~the latter~~ is work by the group at Sandia National Laboratory, [Sch89] in which a site was found with substantially less background and results presented for a limit on neutrons produced in electrolytic fusion. Similar results from the Frejus tunnel in France were also presented in Santa Fe [DeC89]. However, in a BYU collaboration at the Grand Sasso Laboratory deep underground [Ber89] involving 'electrolytic infusion of deuterons into titatnium' cathodes, the detection of 350 +/- 51

counts of 2.5 MeV neutrons and indicates consistency with their initial results, though unfortunately their background is 100 - 1000 times higher than previous measurements of the neutron level in the Grand Sasso Laboratory [Ale89] so that the excess neutron yield reported is still a fraction of the background and the advantages of the underground site are not fully realized.

At the Santa Fe workshop, Moshe Gai of Yale presented results obtained in collaboration with Brookhaven National Laboratory, in which no neutrons were detected from electrolytic cells above the detection limit of 10**-25 n per D - D pair/sec [Gai89]. In a recent preprint Salamon et al. from the University of Utah [Sal89] report measurements of neutrons in the Pons Laboratory over 67 hours with several electrolytic 'CF' cells operating. They observed no neutrons above background and quote a limit of 1 neutron per second emitted by any of the cells, comparable to the limits in Table II.

Many claims have been made for the production and detection of neutrons produced in electrochemical cells, but these claims have mostly been withdrawn or moderated by the discovery of difficulties with the counter -- particularly with the BF3 counters used. Some counters are sensitive to humidity; others to microphonic noise (vibration), or to other afflictions. Some limits on reported neutron fluxes, compared to the flux reported by the BYU group, are summarized in Table I.

IIIc. Dry Fusion.

Results presented in April 1989 by a group at Frascati [DeN89] opened a different area of investigation for the study of D + D cold nuclear fusion. In this work, deuterium gas at 60 atmospheres pressure (60 bar) was allowed to contact titanium lathe turnings in a stainless steel reaction vessel, and the

*Additional care is needed as the rate of cosmic ray neutrons can fluctuate by 20% or more with variations in barometric pressure or with solar activity.

temperature of the sample was varied either by heating or by cooling. No neutrons were observed from the hydriding reaction, at room temperature or at elevated temperature, when viewed by a nearby BF3 counter. However, after cycling to liquid nitrogen temperature (77R K), bursts of counts were observed -- typically on the order of 20 counts per burst over a period of 60 microseconds. One set of counts, obtained by cycling to nitrogen temperature, shows neutrons mainly in these bursts.

A different type of neutron emission was also claimed by the Frascati group [DeN89] following warming from nitrogen temperature over one weekend. The observed count rate follows a bell-shaped curve, rising to a peak of 300 neutrons per 10/minute counting interval, over some 5 hours. These important experimental results provoked great effort toward verification, both at Frascati and elsewhere. A recent private communication from M. Martone at Frascati indicates that neither the burst results nor the continuous neutron emissions from the D-Ti system or from any other dry fusion activity at Frascati have been confirmed. In addition, electrochemical cells produced no observable neutrons, and their operation was terminated in July.

New Energy Times Archive

A group at LANL [Men89] has conducted dry fusion work with Ti and Pd, and has presented results both at the Santa Fe meeting and in a preprint. This group at LANL uses high-efficiency systems that moderate any fast neutrons emitted from experimental cells, detecting the moderated thermal neutrons in 3He gas counters. Some bursts of neutron counts are observed 3000-5000 seconds after the sample is removed from liquid nitrogen, at sample temperatures of about -30 C. These bursts, of up to 100 neutrons at most, are seen in about 30% of the samples tested. An attempt to reproduce this effect at Sandia National Laboratory yielded negative results [But89].

Finally, a conference report from the Bhabha Atomic Research Center (BARC), India, [Iye89] provides text and tabulated results from several groups at BARC. Fig. 1 of the BARC report shows counts from neutron detectors observing a large electrolytic cell, with an estimated 2x10**7 neutrons in the 5 minutes following an overpower trip of the electrolyzer. Tritium and neutrons are observed at BARC from cathodes fabricated of PdAg alloy as well as from pure Pd. Figure 2 of the BARC report shows dry fusion 3He neutron-counter output during gradual rise of temperature of 20 g of Ti while deuterium gas was being pumped off. It is also commented that samples could be loaded with deuterium gas at 1 bar and 900 C, and that "one such disc shaped button loaded on Friday 16th June began emitting neutrons on its own, almost 50 hours after loading. It produced (about) 10**6 neutrons over a 85-minute active phase. The background neutron counter did not show any increase in counts over this time."

IIId. Fracto-Fusion and Other Effects.

In 1986 a group at the Institute of Physical Chemistry in Moscow reported that when a single crystal of LiD was fractured by a device powered by an air gun, a few neutrons appeared to be produced [Klu86]. These were attributed to internal sparks associated with fractures in the material. Recently the same group reported that when titanium chips were agitated in a drum with heavy water and deuterated polypropylene, using steel balls and vibration at 50 Hz, neutrons were observed for a few minutes at a rate of 0.31 +/- 0.13 counts/sec [Der89]. After a few minutes no neutrons were seen. Neutron emission during plastic deformation of deuterium-containing solids under pressure is reported by Yaroslavskii [Yar89] from 'rheological explosions' induced by rotating the anvils of a press on a rock sample to which grains of beryllium bronze and D20

New Energy Times Archive

have been added. Typically, 1000 pulses are detected in a burst, interpreted by the experimenter as arising from 10**6 neutrons.

Another effect reported recently is that of Beuhler et al. [Beu89] who accelerated singly charged clusters of heavy ice, on the order of 100 molecules, to voltages up to 325 keV. They obtained ~~some~~ evidence of the p + T branch, and more recently of n + 3He, at a rate of about 1 per 10**11 clusters.

These effects are not fully understood at present, the experiments are difficult and need to be repeated by others. If confirmed, a quantitative understanding of such effects could lead to interesting physics. However, the scale of energies in internal sparks and in the cluster acceleration experiments is still orders of magnitude higher than the one relevant to room temperature fusion.

IIIe. Secondary Neutron Yields.

There are severe problems of consistency between the numbers of tritium atoms detected in some of the experiments discussed above and the number of neutrons. The BARC abstract reads, "The total quantity of tritium generated corresponds to about 10**16 atoms suggesting a neutron to tritium branching ratio less than 10**-8 in cold fusion." But, as discussed above there must be at least one neutron per 100,000 tritons if the observed tritium were originating from fusion, 1000 times more than was observed!

III.f. Summary

Most of the experimental measurements of neutrons associated with cold fusion give upper limits that are vastly smaller than that consistent with observable heat production by D + D fusion. The lack of neutrons is a very serious indicator that the early optimism in this field was misplaced.

IV. CHARGED PARTICLES AND GAMMAS

A few experiments [Por89, Pri89, Reh89, Sun89] to measure the 3 MeV protons and/or the 1 MeV tritons produced in the reaction, D + D --> T + p, have been reported; they are summarized in Table II below. A variety of different methods has been used, but the lowest limit on charged-particle production appears to be that set by Price using plastic track detectors. Their setup was designed so that the light water control cell matched the heavy water cell as closely as possible. Electrolysis was performed for 13 days, and the cathode stochiometry was determined to be Pd(H,D)0.8. Both cells showed track production rates that agreed and were consistent with the alpha-particle emission rate for native Pd foils due to trace (ppm) impurities of the natural 238U and 232Th decay chains; however, no tracks due to protons with energies between 0.2 and 3 MeV or tritons with energies between 0.2 and 1 MeV were found. From these data Price [Pri89] set limits on the fusion rate of less than 0.002 per cm3 per second. This value results in an upper limit of 8.3x10**-26 fusions per D - D pair per second. This is about an order of magnitude lower than the limits obtained using Si surface barrier (SSB) techniques.

A limit on the fusion rate of 0.028 per cm3 per second or 1.2 x 10**-24 fusions per D - D pair per second was obtained by Ziegler [Zie89] using a SSB technique. Porter [Por89] used a SSB detector to view the back of a 76 micron thick Pd foil cathode in a heavy water electrolysis cell. They obtained a limit of less than 6x10**-25 protons per dd pair per sec at the 2 sigma level; chemical

analysis of their electrolytes showed no evidence for anomalous increases in tritium concentrations. Sundqvist et al. [Sun89] also used a SSB technique to detect protons. The detector was placed close to Pd foil cathodes that were thin enough to allow all the protons produced to escape from the foil. All of their runs gave a null result within the statistical errors, resulting in a fusion rate of -2.1 (+/- 2.2) x 10**-24, if a bulk process is assumed.

Recently, Rehm [Reh89] has reported using a proportional counter to search for charged particles from electrolytic cells with Pd and Pt electrodes in 0.1 M LiOD in D2O. They obtained an upper limit of 4 x 10**-23 fusions per D - D pair per second, not as low as the limits using the other methods.

In summary, a variety of experimental techniques has been used in

New Energy Times Archive

searches for charged particles; all of them set very low limits on fusion occurring via the D + D --> T + p. Most of these results set limits that are considerably less than Jones' [Jon89a] value of 1 +/- 0.2 x 10**-23 (undertainty calculated by Jones), or 1.00 +/- 0.82 x 10**-23, (uncertainty calculated by Sundquist [Sun89]) fusions per D - D pair per second for the D + D --> 3He + n channel obtained from neutron measurements.

The upper limit of Price [Pri89] of 8x10**-26 fusions per DD pair per second is much below the average ~~low~~ rate inferred from the neutron measurements of Jones or even those of Menlove [Men89]. The extremely low limits which the searches for charged particles (either protons or tritons) place on their production is thus inconsistent with the reported production of either neutrons or tritium via the cold fusion reaction.

Less sensitive measurements have also been published searching for helium by mass spectroscopy, for instance by [Lew89a]. Both the gaseous products of electrolysis and the Pd electrode were examined. Helium is expected to be trapped in the palladium lattice, so the Pd electrodes were melted after being used in the electrolysis of heavy water and the evolved gases analyzed: no helium was found above a limit of 8x10**11 He atoms per cm3 of Pd. A similar limit was set by the Harwell (U.K.) group [Wil89b]. Although such limits are not as stringent as the ones set by direct counting of particles, the levels of helium corresponding to the background are still several thousand times below that corresponding to 1 Watt of D + D fusion for one hour.

IVa. GAMMA-RAY SEARCHES

A rare branch of the D + D reaction proceeds through capture, in which a 24-MeV gamma ray is emitted. Similarly, the p + D reaction is associated with a 5.49 MeV gamma ray. In several published searches no gamma rays that would be associated with the D + D or p + D capture reactions were seen. They include a report by Henderson [Hen89] who cites limits around 10**-23/sec 24-MeV gamma rays emitted per deuteron in various cells. Porter [Por89] reports no 5.5 MeV gamma rays -- though no absolute limit is quoted. They also comment on the absence of K X-ray production from Pd. Greenwood [Gre89] reports limits of 10**-23 for gamma rays above 1.9 MeV. Other negative results are quoted in the Santa Fe abstracts without quantitative detail. Lewis, et al., [Lew89a] report fewer than 4x10**-25 5.5-MeV gamma rays per second per D in a Pd cathode, and fewer than 2x10**-23 24-MeV gammas per second per D. Negative results from measurements of gamma rays were also reported recently from Utah on electrolytic 'CF' cells in the Pons Laboratory over 831.5 hours during which several cells were operating [Sal89].

New Energy Times Archive

V. TRITIUM

One branch of the D + D reaction produces tritons and protons. Searches involving the direct detection of charged particles have yielded stringent negative results; so has the lack of neutrons. Searches have also been made for the tritium accumulated during the electrolysis of D2O with palladium cathodes, determining tritium content by detecting the radioactive decay of tritium. In such experiments it is important to determine the initial tritium content of the heavy water and recognize that the electrolysis of the heavy water will enrich the naturally occurring tritium in the heavy water.

The detection of tritium by measurement of its beta decay is

inherently a less sensitive probe of the D - D reaction than the direct measurement of neutron or charged particle production. About 10**7 tritium atoms give 1 decay by beta emission per minute. The tritium content of normal water is about 10**-18 relative to hydrogen but, as discussed in Appendix B, the normal manufacturing of heavy water also enriches tritium, and thus heavy water currently being sold gives between 120 and 180 disintegrations per minute (dpm) from tritium decay.

Va. Null Experiments.

Most reports to date of excess tritium in electrolytic cells can be accounted for by the electrolytic enrichment process. This includes the original report by Fleischmann and Pons [Fle89], and experiments at ANL [Gre89, Red89], BNL [Dav89, McB89, Wie89], Cal Tech [Lew89b], CRNL [Sco89], INEL [Lon89], LLNL [Ald89], NRL [Eri89], ORNL [Ful89, Sco89], Sandia [Nar89], SRL [Ran89], Texas A & M [Mar89], and Utah [Wad89], [Wil89].

Vb. Tritium Bursts.

A few experimenters report occasional irreproducible amounts of excess tritium in D2O samples from their electrolytic cells after days of operation. This includes observations by Storms [Sto89] at Los Alamos, and Fuller [Ful89] and Scott [Sco89] at ORNL. The ORNL experiments show single cases of excess tritium of short duration, after which a cell returns to background level. Storms reports excess tritium, 100 times background, in two cells out of 70.

Vc. Closed Cells - Correlation with Excess Heat.

Four groups [McB89, McC89, Sco89, Mar89] have looked for tritium production in closed electrolytic cells. Since the only tritium in the cell is that contained in the initial fill of heavy water, except for that which may be contained in the cahtode, these experiments detect only tritium generated from the electrolytic process. These experiments detect only the tritium from the electrolytic process except for that which may be contained in the Pd cathode. In general, the deuterium inventory in the cathode is negligible compared with the D2O. Only that tritium formed within the cathode and which remains there because of slow diffusion is unaccounted for. In these experiments the total excess tritium formed in the D2O is less than 10**4 T atoms/sec. If this tritium is produced by the D - D reaction, then the maximum excess power (cold fusion power) is 10**-5 milliwatts. In one experiment [Wad89] in an open cell there was a heat burst reported of 35 watts for 90 minutes (187,000 joules). No excess tritium above the electrolytic enrichment was measured after the burst. Clearly the heat burst does not come from the D - D reaction.

New Energy Times Archive

Vd. High Levels of Tritium.

Two groups [Pac89, Iye89] find tritium at levels of 10**12 to 10**14 T atoms/ml D2O after periods of electrolysis of the order of hours. This amount of tritium cannot be produced by electrochemical enrichment with the D2O volume reductions reported. The results of the Bockris [Pac89] group at Texas A & M for cells in which excess tritium was found are given in Table 1 of their paper. Excess tritium is not found in all of their cells. A listing of cells in which no excess tritium was found is given in their Table 4. The Bockris cells are 0.1 M in LiOD and have nickel anodes. They precipitate nickel oxide during the electrolysis; some nickel is also electroplated out on the palladium cathode. In one experiment, A8, the specific activity of the D2 gas produced by the electrolysis was measured. It is 100 times that of the electrolyte.

D2 (gas) containing tracer amounts of tritium and in equilibrium with D2O (liquid) has a specific activity that is lower by 0.6 than the D2O (liquid). If the tritium is formed during electrolysis, this result (T/D ratio in the gas 100 times that in the liquid) suggests that it is formed in the chemical species DT and that the tritium in the liquid D2O is the result of hot atom processes or slow isotopic exchange of the DT (gas) with D2O (liquid) [Big89b].

Wolf et al. [Wol89] at Texas A & M have looked for neutron production in Bockris type cells. An upper limit to the production rate is 1 neutron/second, which is 10**-10 times that of the tritium production rates reported with similar cells by Packham et al., [Pac89]. This large discrepancy from the equal production rates for neutrons and tritons required by the branching ratio in the fusion reaction, discussed in section II, is inconsistent, by a factor of 10,000 to 100,000, even with the secondary neutrons that must accompany the tritons produced from nuclear fusion. Thus, the excess tritium found in the Bockris electrochemical cells cannot be the result of nuclear fusion in the cell.

The most extensive and systematic search for tritium in the electrolysis of D2O with Pd cathodes has been carried out by Martin [Mar89] at Texas A & M. He has used both open and closed cells. His cathodes come from either Johnson & Mathey, a major supplier, or Hoover and Strong, who supplied the cathodes to the Bockris [Pac89] group. He has operated cells with Pt, Ni wire and Ni gauze (obtained from Bockris) anodes. In none of his cells does he find any excess tritium beyond that expected from electrolytic enrichment. Nor does he find any neutrons. Two of his cells produced excess heat but no tritium. In short, he has been unable to reproduce the results of the Bockris group.

The BARC [Iye89] group have found amounts of tritium comparable to the Bockris group in the D2O electrolyte from cells in which electrolysis was carried out for a few days with currents varying between 1 to 100 amperes. There is again a factor of 1000 internal inconsistency between the measured neutron yields and the neutrons that have to be there if this tritium was produced by fusion -- even if one assumes a drastic modification of the branching ratio in the D + D reaction.

The experiments to date include many with null results. The few experiments in which excess tritium is reported have not been reproducible by other groups. These measurements also contain a serious internal inconsistency, in that the ratio of measured neutrons to tritium is smaller by orders of magnitude than what is consistent with a fusion process. Additional investigations are desirable to clarify the origin of the excess tritium that is occasionally observed.

VI. UNCONVENTIONAL EXPLANATIONS

VIa. D - D Reactions.

The data on fusion products, even where positive results are reported, give rates far below those that would be expected from the levels of heat reported in some electrolysis experiments. Some proposals invoke mechanisms where the reaction heat from the D + D --> 4He process would go entirely into lattice heat, rather than a photon [Wal89,Hag89]. Analogies have been made with the internal conversion process, and with the Mossbauer effect. Neither of these analogies is applicable to 4He.

New Energy Times Archive

Internal conversion allows an atomic electron of an excited nucleus to carry off the reaction instead of a photon. This process is understood quantitatively -- it is dominant in heavy atoms with tightly bound inner electrons and for low energy (less than 1 MeV) photons. In helium the atomic electrons are loosely bound and the photon is 23.8 MeV -- there can not be any appreciable coupling between the photon and the atomic electrons, and internal conversion or any related process cannot take place at anywhere near the rate that would be required. The proposal of Walling and Simons invokes enhancement of internal conversion by electrons of high effective mass appropriate to the solid; as we have discussed above, such band structure effects can in no way play the role of real high-mass electrons either in screening at sub-atomic distances or in the internal conversion process at MeV energies. Furthermore, although Walling initially reported 4He in appropriate amount to explain claims of excess heat, this result was due to atmospheric contamination.

In the Mossbauer effect the momentum of a very low energy (below 100 keV) photon is taken up by the entire lattice in a coherent mode, but not its energy. The process cannnot be relevant to the present process.

More generally, there are numerous reactions analogous to the D + D or p + D fusion process, in which gamma rays of comparable energy are emitted from low- energy nuclear reactions (thermal-neutron capture gamma rays). The cross sections for capture have been studied carefully and quantitatively; they are essential to the operation of fission reactors. If there were any anomalous processes in which a capture gamma ray were totally suppressed in favor of direct conversion into lattice heat, this would have almost certainly been noticed as a discrepancy in cross sections with major implications for the operation of reactors. After four decades of extensive study of the processes relevant to the operation of fission reactors the possibility is remote that an entirely new process, that could dominate these nuclear reactions, would have remained hidden.

VIb. Other Fusion Reactions.

In addition to the D - D and p - D reactions discussed thus far, there are several other nuclear reactions that would be substantially exotherimic if they could take place at a reasonable rate at low energy. Among these are deuterons fusing with 6Li, 7Li, 16O, as well as various Pd isotopes. The reaction rates for these processes are again governed by the Coulomb barrier and for fusion at low temperatures this becomes even more overwhelming than for D + D. The process on Li isotopes, where the nuclear charge is three, is relatively the

most favorable, but even these would give fusion rates that are enormously suppressed even in comparison with that for the D + D reaction; the rates are some forty orders of magnitude slower. The D + 6Li and p + 7Li reactions would not produce neutrons or direct gamma rays -- all the energy would be in alpha particles (4He nuclei), but these in turn would cause Coulomb excitation of the Pd. No such gammas have been seen.

VII. SEARCH FOR PRODUCTS OF COLD FUSION IN THE EARTH

Products of low-level cold fusion have been inferred to be produced by natural geologic processes [Jon89a, Jon89b]. The 3He:4He ratio is anomalously high in volatiles from deep-source volcanoes such as Hawaii, Iceland, and Yellowstone [Lup81, Kur83, Mam84]; anomalous T is also

New Energy Times Archive

suggested by fragmentary data [Ost84, Jon89c], and production of other radiogenic products such as 36Cl have been predicted [Kyl89]. Although the high 3He values have previously been considered relict from early earth processes, presence of anomalous T or 36Cl (beyond that due to bomb tests) would be definitive evidence of natural cold fusion at depth within the earth. Implications would be major for geophysical problems such as heat-flow modelling, element-distribution with depth, and composition of the Earth's core.

Although some isotope geochemists see no evidence for naturally occurring cold fusion [Cra89], several government and university labs are searching for evidence of such fusion processes as recorded by volcanic volatiles [Jo89c, Kyl89, Gof89, Loc89, Qui89] independently of laboratory fusion experiments, such geologic studies could add much to understanding of the behavior of volcanic volatiles. No rigorous results are yet available, but experiments proposed or underway at Brigham Young, Los Alamos, Lawrence Livermore, New Mexico Tech, and the U.S. Geological Survey (Denver) should yield data within 6 months to 1 year.

VIII. SUMMARY

Careful experiments have been carried out to search for the expected products of cold fusion. None have seen these products within many orders of magnitude of the level that would be expected from the heat production reported in electrolysis. Some experiments report neutrons or tritium at a much lower level -- however, the rates of these two fusion products (measured in the same experiments) are inconsistent with each other, again by large factors. In particular, reported tritium production is accompanied neither by the one 2.45- MeV neutron per T observed in all other low-energy D - D fusion, nor by the 10**-5 14-MeV neutron per T that would be produced by the 1.01-MeV T itself in the D - rich environment.

The neutron bursts reported in some experiments are not reproducible by other experimenters, or even by those who report them. While some mechanism might produce small bursts of hot fusion (e.g. high voltage internal sparks associated with fracture of the material at certain temperatures), the present experimental evidence is not readily reproducible, and even if real, the phenomenon does not appear to be related to "cold fusion" as postulated in the heat production experiments.

New Energy Times Archive

If there were such a process as room temperature fusion, it would require

(a) the circumvention of fundamental quantum mechanical principles, which have been tested against measurements of barrier penetration (such as the systematics of spontaneous fission and alpha radioactivity lifetimes and those of nuclear cross sections),

(b) drastic modifications of branching ratios in the D + D reaction, and

(c) the invention of a new nuclear reaction process.

==========
=

TABLE I. SOME COLD FUSION NEUTRON RATES

Authors	Reference	Neutrons per DD pair per seca	Yield Normalized to Jones et al. [Jon89a] neutronsb
Fleischman et al.	[Fle89]	10**-22	10
Broer et al.	[Bro89]	< 2.2x10**-24	< 0.2
Williams et al.	[Wil89]		< 0.2
Lewis et al.	[Lew89a]	< 1.5x10**-24	< .15
Alber et al.	[Alb89]	< 5x10**-25	< 0.05
Gai et al.	[Gai89]	< 2x10**-25	< 0.02
Schriber et al.	[Sch89]		< 0.02
Kashy et al.	[Kas89]	< 10**-25	< 0.01
De Clais et al.	[DeC89]		< 0.01 < 0.001

a assuming that neutrons are produced throughout the volume of Pd.

b for comparison one watt of heat production by D - D fusion would correspond to 0.9x1012 in these normalized neutron yield units.

New Energy Times Archive

TABLE II. SOME COLD FUSION FAST CHARGED PARTICLE RATES

Authors	Reference	Protons per DD pair per seca	Yield Normalized to Jones et al. [Jon89a] neutronsb
Jones et al.	[Jon89a]		1.0
Rehm et al.	[Reh89]	< 4x10**-23	< 4
Schrieder et al.	[Sch89]	< 3.1x10**-24	< 0.31c
Sundquist et al.	[Sun89]	< 2x10**-24	< 0.2
Ziegler et al.	[Zie89]	< 1.2x10**-24	< 0.12c

Porter et al.	[Por89]	< 6.7x10**-25	< 0.07
Price et al.	[Pri89]	< 8.3x10**-26	< 0.008

a assuming that particles are produced throughout the volume of Pd.

b for comparison one watt of heat production by D - D fusion would correspond to 0.9x1012 in these units.

c Rehm et al. comment that the choice of the low-energy cutoff (e.g. 1 MeV in Ref. [Zie89]) restricts the emission angle of the protons with respect to the foil to a small cone representing only a few of the total solid angle. This effect seems to have been neglected in the efficiency calculations for the limits quoted by these authors.

New Energy Times Archive

REFERENCES

[Alb89] D. Alber, O. Boebel, C. Schwarz, H. Duwe, D. Hilscher, H. Homeyer, J. Jahnke, and B. Spellmeyer, Z. Phys. A 333, 319 (1989).

[Ald89] F. T. Aldridge, R. J. Contolini, M. Y. Ishikawa and D. R. Slaughter, LLNL, communicated J. F. Holtzrichter to ERAB 8 September 1989.

[Ale89] R. Aleksan, J. Bouchez, M. Cribier, E. Kajfasz, B. Pichard, F. Pierre, J. Poinsignon, M. Spiro, and J. F. Thomas, Nucl. Inst. Meth. A274, 203 (1989).

[Bal84] D. V. Balin, E. M. Maev, V. I. Medvedev, G. G. Semenchuk, Yu.V. Smirenin, A. A. Vorobyov, An.A. Vorobyov and Yu.K. Zalite, Phys. Letts. B141, 173 (1984).

[Bar87] C. A. Barnes, K. H. Chang, T. R. Donoghue, C. Rolfs and J. Kammeraad, Phys. Letts. B197, 315 (1987).

[Ber89] A. Bertin, M. Bruschi, M. Capponi, S. De Castro, U. Marconi, C. Moroni, M. Piccinini, N. Semprini-Cesari, A. Trombini, A. Vitale, A. Zoccoli, S. E. Jones, J. B. Czirr, G. L. Jensen, and E. B. Palmer, Il Nuovo Cimento, 101A, 997 (1989).

[Beu89] R. J. Beuhler, G. Friedlander, and L. Friedman, Phys. Rev. Letts. 63, 1292 (1989).

[Big89a] J. Bigeleisen "Tritium Enrichment in the Electrolysis of D2O" Workshop on Cold Fusion Phenomena, Santa Fe, NM, 22-25 May 1989.

[Big89b] J. Bigeleisen, letter of 26 August 1989 to J. O'M. Bockris.

[Bro89] Broer et al., Phys. Rev. C preprint.

[But89] M. A. Butler, D. S. Ginley, J. E. Schirber, and R. I. Ewing, preprint.

[Cra89] H. Craig, letter to P. Lipman, 28 September 1989.

[Dav89] A. J. Davenport and H. S. Isaacs, BNL, communicated by P. Bond to ERAB 1 September 1989.

[DeC89] De Clais et al., Sante Fe meeting

[DeN89] A. De Ninno, A. Frattolillo, G. Lollobattista, L. Martinis, M. Martone, L. Mori, S. Podda and F. Scaramuzzi, Europh. Lett. 9(3), 221 (1989).

[Der89] B. V. Derjaguin, A. G. Lipson, V. A. Kluev, D. M. Sakov, and Yu. P. Toporov, Nature 341, 492 (1989).

[Eri89] J. Eridon, NRL, 17 August 1989 communication to ERAB.

[Fle89] M. Fleischmann and S. Pons, J. Electroanalytic Chem. 261, 201 (1989).

[Ful89] E. L. Fuller, ORNL Memo of 29 August 1989 to B. R. Appleton.

[Gai89] M. Gai, S. L. Rugari, R. H. France, B. J. Lund, Z. Zhao, A. J. Davenport, H. S. Isaacs and K. G. Lynn, Nature 340, 29 (1989).

[Gar89] R. L. Garwin, private communication.

[Gof89] F. E. Goff, letter to P. Lipman, 24 August (1989).
[Gre89] L. R. Greenwood and C. A. Melendres, ANL, communicated to ERAB, 23 August 1989.
[Hag89] P. L. Hagelstein "On the Possibility of Coupling Nuclear Fusion Energy to Phonons" and "A Simple Model for Coherent Fusion in the Presence of a Lattice" preprints, August 1989.
[Hen89] R. A. Henderson, et al. (Poster presented at Sante Fe Cold Fusion Meeting), Lawrence Berkeley Laboratory Preprint LBL-2740, submitted to J. Fusion Energy.
[Iye89] P. K. Iyengar, "Cold Fusion Results in the Bhabha Atomic Research Center (BARC) Experiments". Paper presented at the Fifth International Conference of Emerging Nuclear Energy Systems (ICENES V). Karlsruhe, 3-6 July 1989.
[Jen89] R. J. Jensen, ADR:89-409, Report to ERAB, 13 September 1989.
[Jon89a] S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne, S. F. Taylor and J. Rafelski, Nature 338, 737 (1989).
[Jon89b] Jones et al., draft preprint (1989).

[Jon89c] Jones, priv. comm. to P. Lipman, 8 September 1989.
[Kas89] E. Kashy, W. Bauer, Y. Chen, A. Galonsky, J. Gaudiello, M. Maier, D. J. Morrissey, R. A. Pelak, M. B. Tsang and J. Yurkon, Phys. Rev. C 40, R1 (1989).
[Klu86] V. A. Kluyev, A. G. Lipson, Yu. P. Toprorov, B. B. Deryagin, V. I. Lushchikov, A. V. Strelkov, and E. P. Shabalin, Sov. Tech. Phys. Lett. 12, 55 (1987).
[Koo89] S. E. Koonin and M. Nauenberg, Nature 339, 690 (1989).
[Kra87] A. Krauss, H. W. Becker, H. P. Trautvetter, C. Rolfs and K. Brand, Nucl. Phys. A465, 150 (1987), and references therein.
[Kur83] M. Kurz, W. J. Jenkins, S. R. Hart and D. Clague, Earth & Planetary. Sci. Lett. 66, 388-406 (1983).
[Kyl89] P. R. Kyle, Priv. Comm. to P. Lipman, 16 August 1989.
[Lew89a] N. S. Lewis, C. A. Barnes, M. J. Heben, A. Kumar, S. R. Lunt, G. E. McManis, G. M. Miskelly, R. M. Penner, M. J. Sailor, P. G. Santangelo, G. A. Shreve, B. J. Tufts, M. G. Youngquist, R. W. Kavanagh, S. E. Kellogg, R. B. Vogelaar, T. R. Wang, R. Kondrat and R. New, Nature 340, 525 (1989).
[Lew89b] N. Lewis, California Institute of Technology Memo of 28 August 1989 to ERAB.
[Loc89] J. P. Lockwood, letter to P. Lipman, 18 September (1989).
[Lon89] G. R. Longhurst and A. J. Caffey, INEL, Communicated by S. C. T. Lien to ERAB 5 September 1989; G. R. Longhurst, T. J. Dolan and G. L. Henriksen, INEL, EGG-M-89203, 19 May 1989.
[Lup89] J. E. Lupton and H. Craig, Science 214, 13 (1981).
[Mam89] Mamyrin and Tolstikhin, Helium Isotopes in Nature: Elsevier, Amsterdam (1984).
[Mar89] C. R. Martin, Texas A & M, Letter of 11 September 1989 to ERAB.
[McB89] J. McBreen, report to ERAB, 1 September 1989.
[McC89] D. R. McCracken, J. Pauette, H. A. Boniface, W. R. C. Graham, R. E. Johnson, N. A. Briden, W. G. Cross, A. Arneja, K. W. Chambers, A. K. McIlwain, E. M. Attas, and R. Dutton, J. of Fusion Energy, in press.
[Men89] H. E. Menlove, M. M. Fowler, E. Garcia, A. Mayer, M. C. Miller, R. R. Ryan, aBD S. E. Jones, preprint submitted to Nature 2nd revision, 13 October 89.
[Nar89] A. Narath, Sandia Memo of 28 August 1989 to ERAB.
[Ost84] Ostlund and Mason, Atmospheric Tritium 1968-1984, Tritium Laboratory Rept. No. 14, University of Miami, Miami, Florida.
[Pac89] N. J. C. Packham, K. L. Wolf, J. C. Wass, R. C. Kainthla, and J. O'M. Bockris, J. Electroanalytical Chem., in press.
[Pet89] R. D. Petrasso, X. Chen, K. W. Wenzel, R. R. Parker, C. K. Li and C.

New England Times Archive

Fiore, Nature 339, 183 (1989); ibid 667 (1989).

[Pit89] W. G . Pitt, J. N. Harb, and C. J. Farahmandi, BYU preprint, 13 October 89.

[Por89] Porter et al. ("Search for Energetic Charged Particle Emission from Deuterated Ti and Pd Foils, J. Fusion Technology, submitted 15 July 1989); LBL preprint 27523.

[Pri89] P. B. Price, S. W. Barwick, W. T. Williams, and J. D. Porter, preprint submitted to Phys. Rev. Letts., 14 July 1989.

[Qui89] J. Quick, priv. comm. to P. Lipman, 5 July 1989.

[Ran89] H. W. Randolph, SRL-ELC-89007, 31.

[Red89] L. Redey, K. Myles, D. Dees, M. Krumpelt and D. R. Vissers, ANL, communicated by A. Schriesheim to ERAB, 11 August 1989.

[Reh89] K. E. Rehm, W. Kutschera, and G. J. Perlow, preprint.

[Sal89] M. H. Salamon, M. E. Wrenn, H. E. Bergeson, K. C. Crawford, W. H. Delaney, C. L. Henderson, Y. Q. Li, J. A. Rusho, G. M. Sandquist, and S. M. Seltzer, preprint submitted to Nature.

[Sch89] J. E. Schirber, M. A. Butler, D. S. Ginley, and R. I. Ewing, preprint submitted to Fusion Techn.

[Sco89] C. D. Scott, ORNL Memo of 29 August 1989 to B. R. Appleton.

[Sto89] E. Storms and C. Talcott, report to ERAB, 3 October 1989.

[Sun89] Sundqvist et al., Uppsala University, Sweden, preprint of ms accepted for publication in Physica Scripta, May 15, 1989.

[Wad89] M. E. Wadsworth, Univ. of Utah, Letter of 6 September 1989 to ERAB.

[Wal89] C. Walling, verbal report at the April 1989 meeting of the Nat. Ac. of Sc.; C. Walling and J. Simons, J. Phys. Chem. 93, 4693 (1989).

[Wie89] H. Wiesmann, report to ERAB, 18 September 1989.

[Wil89] D. E. Williams, D. J. S. Findlay, D. H. Carlson, M. R. Sene, M. Bailey, S. Croft, B. W. Hooton, C. P. Jones, A. R. J. Kucernak, J. A. Mason, and R. I. Taylor, Studies of "Cold Fusion" Electrolytic Cells, preprint.

[Wol89] K. L. Wolf, N. Packham, J. Schoemaker, F. Cheng and D. Lawson. Proc. of the Santa Fe Cold Fusion Workshop, in press.

[Yar89] M.A. Yaroslavskii, Dokl. Akad. Nauk SSSR 307, 369 (1989).

[Zie89] J. F. Ziegler, T. H. Zabel, J. J. Cuoms, V. A. Brusic, G. S. Cargill, III, E. J. O'Sullivan, and A. D. Marwick, Phys. Rev. Lett. 62, 2929 (1989).

New Energy Times Archive

APPENDIX A

NEUTRON DETECTION.

Neutrons from DD fusion can be detected either at their initial energy in the MeV range as "fast" neutrons, or after their energy has been "moderated" by sharing it in successive collisions with light material -- particularly hydrogen. Fast neutrons can be detected by photomultiplier tubes viewing the proton recoil in plastic or liquid scintillation material. Slow neutrons (those that have lost almost all their kinetic energy and are in thermal equilibrium at room temperature) are conventionally detected by the charged particles produced when the neutron is captured with high probability in the nucleus of an atom of 10B (producing an alpha particle), or in a 3He nucleus, producing a recoil proton. A noble gas, 3He is used in the form of a proportional counter, while boron can be used either in the form of BF3 proportional counters or in the solid form, with the boron immersed in plastic or inorganic scintillator viewed by a photomultiplier.

Additionally, neutrons can be detected after moderation by their capture in

some material of very high capture cross section (such as cadmium Cd), which produces several gamma rays that may, in turn, be detected by a photomultiplier viewing a scintillation detector. Similarly, neutrons moderated in water are almost entirely captured on the protons ("radiative capture"), giving rise to a deuteron plus a gamma ray with 2.2 MeV.

Finally, moderated neutrons may be captured in a trace element in the moderator (silver is a detector of choice) to produce a radioactive material that can be transported away from the experimental apparatus and counted separately with high efficiency at low background. The emitted radiation is typically a beta ray (negative electron), or a characteristic gamma ray following the beta decay. Of course, the world has enormous experience since the 1930s in detecting neutrons and in detecting neutrons from the D + D fusion reaction.

APPENDIX B

CONSIDERATIONS IN TRITIUM CONCENTRATIONS.

Tritium is produced in the atmosphere by cosmic ray bombardment. Most of such tritium ends up in the oceans and in rivers. The "natural" abundance of tritium varies widely and was greatly increased by atmospheric testing of thermonuclear weapons in the '50s and in the early '60s. The order of magnitude of tritium in ordinary water is T/H - 10**-18 (1 TU). Sources vary from 1 to 200 TU. The production of heavy water from ordinary water is even more efficient in the enrichment of tritium than deuterium from the feed material. Most of the heavy water currently available is produced by the H2S - H2O dual temperature exchange process (GS process). The tritium content of fresh heavy water produced by the GS process is 68 dpm/ml D2O/TU feed. Processes that are more efficient than the GS process in heavy isotope enrichment will have a minimum tritium specific activity of 50 dpm/ml D2O/TU feed. Heavy water currently being sold on the open market has a specific activity in the range 120 - 180 dpm/ml D2O. There are sources of D2O with specific activity as high as 104 dpm/ml.

Most of the work done to date on the search for tritium produced in the electrolysis of D2O in cells with palladium cathodes has been done in open cells. The measurements are frequently limited to assays of the specific

New Energy Times Archive

activities of the starting D2O and the electrolyte after electrolysis. In general, there have been periodic additions of D2O to replace the D2O decomposed to form palladium hydride and D2(gas). To determine how much tritium, if any, has been produced requires a complete inventory of the tritium at the beginning and end of the experiment. From the data on the current and on the duration of the electrolysis it is possible to estimate the amount of D2O which has been electrolyzed. Electrolysis will enrich the tritium in the D2O of an electrolytic cell. The amount of enrichment is primarily a function of the amount of water electrolyzed for a given type of cathode. It can reach a factor of 5 when 95% of the initial charge of water is electrolyzed. Thus a careful analysis of an electrolytic experiment must be carried out if one is to interpret specific activities of tritium after electrolysis, below 1000 dpm/ml of D2O, as anything other than electrolytic enrichment [Bi].